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BEHAVIOR OF GRAY FOXES IN RAIDING QUAIL NESTS

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A great deal of progress has been made in recent years in the study of nest mortality in game birds. Those who have been engaged in such investigations, however, have felt that the basis for accurate determination of predator guilt from sign left at nests is none too well laid. There is much to be learned before our knowledge is really adequate for accurate analysis of depredations on nests.

During the months of June to August in 1935 and 1936, the authors had occasion to observe and study in some detail the nest-raiding habits of gray foxes at Camp Lee, Virginia. In connection with these studies, the histories of 80 quail nests were completed, and data were obtained also from 8 carefully prepared dummy quail nests. These yielded some interesting information on fox habits which is here presented in the hope of aiding game managers and research workers in game management to distinguish fox depredations on quail nests from those of other predators.

It has long been known that wild animals in captivity will not always react truly to their normal living pattern. To learn, then, how a fox naturally goes about raiding a quail nest and to determine what evidence the animal normally leaves behind, it is obviously desirable to restrict investigations so far as possible in the field. The average quail-nesting environment does not, however, provide ideal experimental conditions. Satisfactory tracking, for instance, is hardly possible in even rather thin stands of broomsedge—cover so frequent in quail environment. To overcome this difficulty, it was decided to transplant quail nests, only those being used that had been hatched off, deserted, or robbed, to sites that would offer favorable tracking conditions. The nests were dug out so as to include the vegetation surrounding them and this helped greatly in preserving a natural appearance in the new location. The transplanted nests were placed in a variety of situations. The margins of eroded and abandoned roads and old foot paths and the edges of feed strips and gravel washes offered good sites suitable for tracking. These edges were frequently traveled by foxes. In some instances tracking spots were improved on the approach side of the nest but in others this was unnecessary, especially when the nest was transplanted just after a good rain.

The nests were not handled directly at any time. They were dug out with shovels and hauled to the new locations on large trays. The eggs used were mostly obtained from deserted or partially destroyed nests though a few were infertile eggs from a commercial

quail hatchery. The eggs also, except those obtained from the hatchery, were not handled.

Since the object of the experiment was to determine the nature of fox behavior in raiding quail nests and not the extent of fox pressure on the nests, it was decided to attract the animals to the vicinity of the nests. For this purpose, fresh fox droppings were used and a single dropping in each case was placed anywhere from a few to several feet from the nest site; this proved very effective.

HISTORY OF NESTS

The individual records for the transplanted nests are:

Nest No. 1

June 15, 1936—Deserted nest transplanted to edge of fox run near old sand pit in stand of broomsedge. At least two foxes had been visiting the sand pit each night and frequently passed within a few feet of the site selected for the dummy nest. Fresh fox droppings had been picked up regularly not more than 100 feet from the nest. Ten unincubated quail eggs were transferred to the nest from one that had recently been deserted. A fresh fox dropping was placed within 2 feet of the nest entrance.

June 16—Three of the ten eggs were missing. No sign of any disturbance to the nest. No trace of egg shell at or around nest. Fresh fox tracks leading directly to the nest. Four additional eggs placed in nest and old dropping replaced by a fresh one.

June 17–25—Daily visits to the nest were made. No more eggs taken although foxes continued to pass regularly. On June 25, one passed within a foot of nest entrance.

Summary—Three of 14 eggs taken by fox. Exposure: ten nights. Nest not disturbed. No egg shell fragments in vicinity of nest.

Nest No. 2

June 25, 1936—A deserted quail nest was transplanted to a site about 10 feet from a little-used dirt road that foxes traveled regularly in going to and from nearby woodland. Nest about 50 yards from dummy nest no. 1. Good natural tracking spot leading to and from nest. A small quantity of liquid from decaying fish was placed at several points within a radius of 50 feet from nest site. Six unincubated quail eggs were put in the nest.

June 26—All eggs missing from nest. No sign of shell fragments anywhere. Nest entrance slightly raised, but no damage to nest structure visible. Numerous fresh fox tracks in front of the nest. Eggs not replaced.

June 28—Nest structure completely pawed out and scattered. Many additional fox tracks in vicinity of nest. Possibly the same fox that visited nest June 26 returned a second time when there were no eggs.

Summary—All 6 eggs in nest were taken. Exposure: four nights. Nest undisturbed on first visit but destroyed second or third night when no eggs were present. No trace of shell fragments found around nest.

Nest No. 3

June 30, 1936—A nest from which young had recently been hatched was placed at the edge of a wash about 40 feet from a main highway and 12 eggs

deposited in it. A fresh fox dropping was placed about 10 feet from nest entrance.

July 1–3—No evidence that foxes had visited or investigated nest. Heavy rains fell on nights of June 30 and July 1. On July 3, fresh fox tracks noted 20 feet from nest, but apparently the nest was passed by unnoticed.

July 4—All 12 eggs missing from nest. Only one small fragment of egg shell found and this was about one foot from nest. Fox tracks present in front of nest entrance. Nest structure undisturbed but some earth had been pawed out on one side. A new clutch of 10 eggs placed in nest and pawed-out earth replaced.

July 5–6—Nest undisturbed. Rained throughout night of July 5. On July 6, two foxes passed within 10 and 20 feet, respectively, from the nest, but did not stop to investigate.

July 7—Nest completely destroyed. All eggs taken from nest. Four small fragments of egg shell found about 30 feet from nest. The nest proper had been pawed out and scattered. Fresh fox tracks noted leading to nest.

July 11—A new nest was placed at the same site and 14 eggs put in it.

July 13—Nest completely destroyed. All 14 eggs missing. Six small fragments of egg shell found about 20 feet from nest. Bottom of nest pawed out and scattered. Fresh fox tracks in front of nest.

Summary—Thirty-six eggs in three separate clutches were taken from this nest by foxes. There were a few small fragments of eggshell found around nest after each robbing. Nest completely pawed out in two instances, undisturbed at the third visit.

Nest No. 4

June 24, 1936—A well-constructed nest that had been deserted was transplanted at the edge of a little-used dirt road in a thin stand of broomsedge. Foxes traveled the road regularly. A fresh fox dropping was placed in road opposite nest. Seven eggs left in the nest.

June 25—Fresh fox tracks noted within 2 inches of nest entrance. Four of the seven eggs missing. No sign of egg shell fragments around nest. Nest structure not noticeably disturbed.

June 26—Remaining 3 eggs missing from nest. No sign of shell fragments around nest. Fresh fox tracks at nest entrance.

Summary—A total of 7 eggs taken from nest in two nights of exposure. No sign of shell fragments around nest. Nest left undisturbed.

Nest No. 5

June 24, 1936—A nest on which an incubating bird had been killed was transplanted to the edge of an eroded slope in a thin stand of broomsedge. Foxes had been noted to pass along this exposed bank regularly. A fresh dropping was placed about 10 feet from entrance on approach side. Six eggs were put in nest.

June 25—All eggs taken; no trace of shell fragments around nest site. Two sets of fox tracks leading to and from nest. The earth around the nest had been pawed out. The nest entrance had been opened up and somewhat disarranged, although nest structure was not seriously disturbed. Eggs not replaced.

June 26—Two foxes again visited and investigated nest, but left without damaging it further.

Summary—Six eggs taken by fox from nest on first night of exposure. No trace of eggshell around nest. Nest structure not seriously disturbed on first night, but completely pawed out on second night when no eggs were present.

Nest No. 6

July 1, 1937—Transplanted well-constructed, deserted nest to edge of eroded slope near main highway. Several fox droppings had been picked up previously near site selected for nest. Fourteen unincubated quail eggs were put in the nest. A fox dropping several days old was placed about 2 feet from nest entrance.

July 2–5—Fox visited the vicinity of the nest each night. On July 5, one passed within 1½ feet of nest entrance and paused to leave a dropping right at the nest entrance. No eggs were taken and nest was undisturbed.

July 6—The top of the nest had been removed and the eggs exposed. One egg missing. Rain fell during night. No evidence of tracks of any kind. Top of nest carefully replaced.

July 7—All 13 eggs taken from nest. Nest left intact. Fresh fox tracks found in front of nest. No eggshell fragments noted anywhere in vicinity of nest site.

Summary—Nest of 13 eggs taken by fox on sixth night of exposure. No disturbance to nest. No shell fragments around nest.

Nest No. 7

July 1, 1936—A nest from which young had hatched was transplanted to the edge of a recently plowed feed strip about 20 yards from a dense deciduous woodland. Foxes traveled feed strip regularly. Fourteen eggs were placed in nest and a fresh fox dropping was left about 3 feet from nest entrance. Liquid from decaying fish was dropped at several points within a radius of 100 feet of nest.

July 2—No activity at nest. Heavy rain fell during night.

July 3—Fresh fox tracks could be trailed to and from nest for 100 feet or more along feed strip. Nest entrance was pushed down—eggs not readily visible. Three of them had been taken. No shell fragments were noted anywhere near nest.

July 4–7—No further activity at nest. Eleven eggs remained in it.

July 11—Fresh tracks leading to nest indicated fox had made a visit. Ten of the 11 eggs had been taken. The eleventh egg had been bitten but left uneaten about 8 inches from nest. Nest structure undisturbed. No loose shell fragments noted around nest. Nest reset—11 additional eggs added.

July 12–15—No activity noted about nest.

July 16—All eggs taken from nest. Nest structure undisturbed. No shell fragments about the nest. Fresh fox tracks leading directly to nest entrance. A fresh fox dropping was picked up within a short distance of nest.

Summary—Three fox visits to nest in 15 nights of exposure. A total of 24 eggs removed from nest. Nest not seriously disturbed. In one instance a partially crushed and uneaten egg was found near nest entrance. No other trace of egg or eggshell noted around nest.

Nest No. 8

July 2, 1936—A nest from which young had been hatched was transplanted to a site adjacent to a little-

used dirt road at a point where opossums had crossed on several occasions. The nest entrance opened away from the road. A clutch of 6 partly incubated eggs was put in the nest and a carcass of a two-day old turkey chick placed about 2 feet from the nest entrance.

July 3–6—No activity at nest noted. Seven crows were walking along road not more than 100 feet from nest on July 4.

July 7—All eggs missing from nest. Clear imprints of fox foot within 4 inches of nest. The bottom of nest had been pawed out—roof of nest remained intact. No sign of shell fragments around nest. Young turkey carcass not touched.

Summary—All 6 eggs removed by fox from nest on fifth night of exposure. Nest considerably disturbed, bottom having been pawed out. No trace of eggshell found around nest.

DISCUSSION

There are, no doubt, many factors that influence the behavior of foxes in raiding quail nests. For instance, the direction from which the nest is approached in relation to the nest entrance would probably materially affect the manner of removing the eggs. In this study the nest entrances in all except one instance were toward what was considered the natural approach side. The one nest which was placed with the entrance away from the natural approach was attacked, however, in the same manner as the other nests, that is from the entrance side with little disturbance to the nest structure. Behavior in this regard is not uniform, however, as in two instances in our Camp Lee studies natural quail nests were approached and destroyed by foxes from the back, the animal in these cases probed through the nest structure and opened up a hole 2 to 3 inches across from which the eggs were removed. This would seem to indicate that the fox by no means follows a set pattern in raiding nests, although the data presented here indicate considerable uniformity in method of attack. Probably the position and general arrangement of the dummy nests influenced the results. Nevertheless the data show quite clearly what is likely to happen when a fox comes upon a nest from the entrance side.

Another factor that may possibly affect the manner in which foxes eat quail eggs is the stage of incubation of the eggs. In this study infertile eggs, unincubated eggs, and eggs in early stages of incubation were used. Most of them were fresh, but several of the sets of infertile eggs were in a state of decay. It is entirely conceivable that the amount of shell left at a nest would be affected by the condition of the eggs. For instance eggs in a decayed condition or in an advanced stage of incubation might be eaten differently than those in early stages of incubation or those not incubated at all. This question is not answered by this study. There is some slight evidence, however, to show that the stage of incubation is a factor, the indication being that more shell is left at nests in which the eggs are in advanced, than at those in which eggs are in early, stages of incubation.

The quantity of food present in the fox's stomach at the time a nest is located also may influence the way in which a nest is destroyed, although there is no present proof that this is a

factor in determining the behavior pattern; in fact the data obtained in this study suggest the contrary. In some instances the fox removed only a part of the clutch, leaving many of the eggs untouched. In cases of this nature, it may be presumed either that the fox was not hungry or that the eggs were not to his liking. In any event, there was little evidence obtained from this investigation to indicate that foxes bite into eggs that they are not inclined to eat.

The results here presented are nowise considered final. There was, it is true, a marked degree of uniformity in the behavior of the foxes in raiding the dummy nests, but the study must be carried further before generalizations are attempted. It is hoped that other studies on fox behavior at nests may be made in various localities.

SUMMARY

Gray foxes may take complete clutches of eggs, up to at least 14 in number, at a single visit to a quail nest. Again they may remove only a fraction of the eggs in a clutch leaving the remainder undisturbed. In practically all cases, they eat quail eggs—shell and all—and leave little debris. They rarely disturb the nest structure in the process of removing eggs from the natural nest entrance. If the nest is approached from the back, an opening is usually probed through the top or side of the nest with a minimum of disarrangement to the nest structure. Foxes apparently return to a nest to remove eggs not taken on the first visit.

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THE USE OF SALT IN CONTROLLING THE DISTRIBUTION OF GAME

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Almost all mammals require some salt and, while the actual requirement may be small, they will take more than this bare minimum and do better generally, if salt is easily accessible and well distributed.

In the Clearwater basin of north Idaho, before the coming of the white man and for some time afterwards, game depended on the salt content of the water from mineral springs and on salt deposited by nature in dry licks. Actually in this area game did not get more than the minimum requirement for analyses of various mineral springs reveal that a thousand gallons of water contain less than 1 lb. of salt. Dry licks were of negligible importance for there is nowhere within the area any sign of great use.

About 15 years ago it was noticed that big game was attracted to salt supplied for livestock and the plan was tried of distributing 2 tons of salt on known game ranges. This was put mostly near the natural licks on Moose Creek, Indian Creek, and Bear Creek, because there was no domestic stock in these areas.

The results of this experiment were so gratifying that the State Fish and Game Department continued, and gradually increased, yearly purchases and distribution until every big natural lick was receiving its quota of salt. The U. S. Forest Service frequently assisted in the transportation and placement of this salt; transportation, incidentally, is the most costly part of the salting program.

About four years ago, salting was greatly increased and the sites changed from the natural licks to the ridges around these licks, mostly on summer ranges. To understand the reasons for the new policy, refer to the map (Fig. 1) which shows the location of the major natural licks on the middle fork of the Clearwater. Most of them are on winter game ranges. They are not distributed evenly throughout the area on either summer or winter ranges. The million acres of the western half has only four licks, none very large, and three of them on winter range. That on the summer range is known as the Oldman Creek Lick, and the other three are Otter Creek, Deadman Creek, and Obia Creek Licks.

During the hard winters of 1931–2 and 1932–3, the loss in deer was so alarming that both forest officers and game wardens began to seek a remedy. They observed that salt placed in natural licks tends to hold game on range in the immediate vicinity of the lick throughout the year. On the summer ranges there were comparatively few licks and an abundance of feed, but on the winter ranges with more licks the grass was killed out and shrubs usually depended on for winter feed were cropped so close during the summer that little remained for winter use and some of the more desirable kinds were beginning to die out. It was found also that the spread of pneumonia, scab mite, ticks, and other diseases or parasites was accelerated.

Change of policy as to salting being

decided upon, the nest thing to find out was what would better conditions. It was observed some 12 or 15 years ago that an occasional elk visited Iron Mountain at the southwest corner of the Clearwater drainage where cattle had been summered for 20 years or more. Despite heavy hunting, the elk increased to 50–60 head centering around this cattle allotment. A similar condition has been observed also on other areas as on Pete King Creek and Clear Creek. It was found, furthermore, that elk would return at the earliest possible time in the spring to salt grounds at high elevation, where some salt remained in late fall.

Hence it was decided to place all salt at summer range elevations, away from all natural licks, and a small amount at

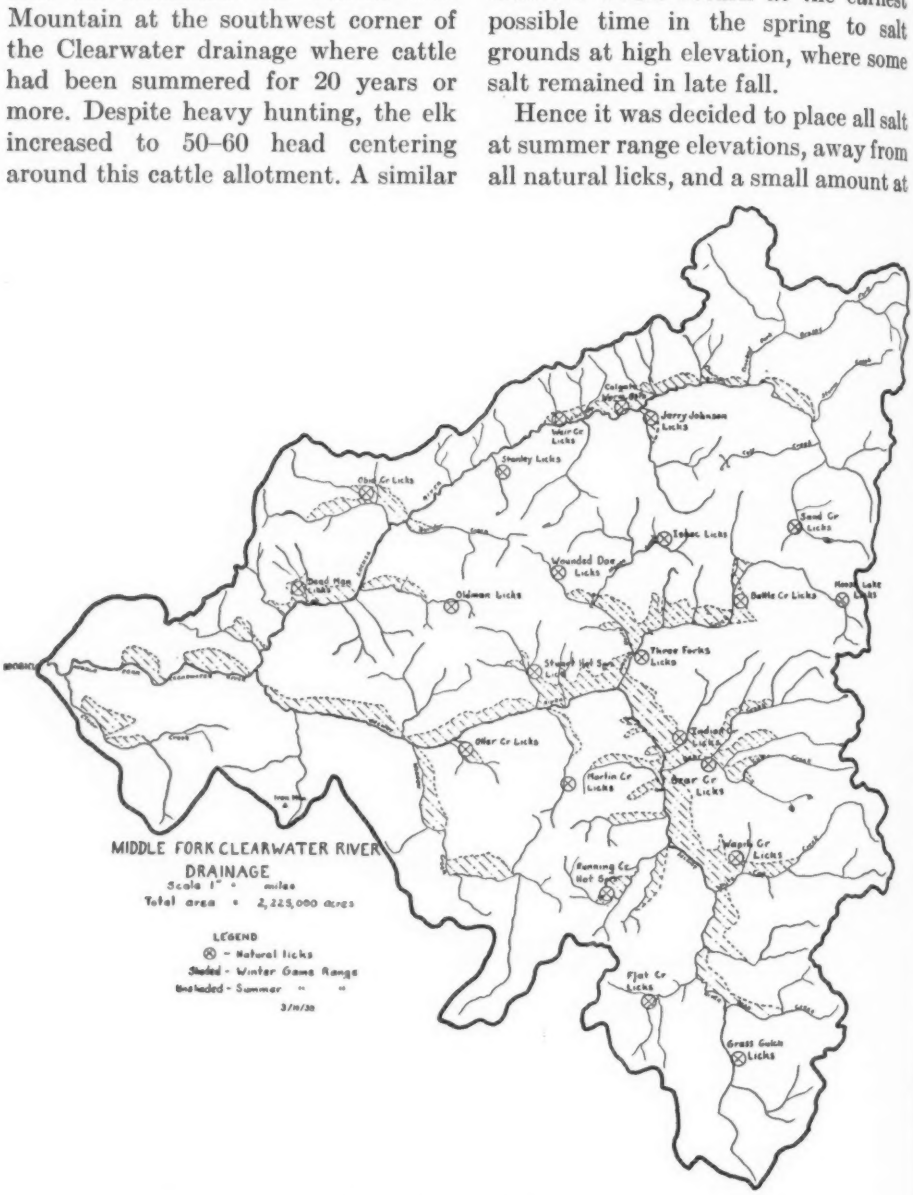

Fig. 1. Location of major natural licks in the drainage of the Middle Fork of the Clearwater River, Idaho.

each salt ground so that distribution might be even throughout the area and the game broken into small groups. As a result of the change more than 90% of the elk and deer stay on the summer ranges until snow forces them down to winter ranges. Game stays in high country until so late in the fall that hunters have to change their hunting areas. In the spring of the year it was noted that elk traveled over as much as 10 feet of packed snow to reach favorite salt grounds. Paul Blum, a local rancher near the Three Forks Lick where more than 100 elk can be seen any time when salt is not available higher up, reported that three days after salt was placed in the high country surrounding the licks he never was able to see more than an occasional stray animal.

It is gratifying to be able to report also that there seemed to be a small increase this summer in sprouts on shrubs of the winter range. Final statement as to what this range improvement will amount to will have to be deferred until more hard winters and dry summers have passed.

Game salt plans of the future must be made by men thoroughly familiar with the area concerned, and consideration given to exposure and snow depths, because these are the factors which, besides feed, determine whether game can winter. On areas which now do not carry game, but which have winter range necessities, it is logical to establish salt grounds with the object of colonizing game. After the game has become at home, the salt grounds can gradually be moved to the summer range.

The chief drawbacks to the salting program on inaccessible areas such as the Selway Fork watershed is the cost of distribution of the salt, about 4 cents per pound at present, and the loss by leaching of salt over winter. Consideration should be given to the provision of covered salt troughs on summer ranges where the slight erosion resulting from constant use will not be objectionable. Use of troughs would prevent loss from leaching and reduce the distribution cost by making possible the placement of two to four years' supply of salt on one pack trip.

It was found by experimentation that it is possible to mix with salt anything from sulphur, tobacco, and bone meal to sheep dip, without materially reducing its attractiveness to game. It may not be unreasonable to assume, therefore, that by proper management and by medication at salting places we may sometime be able to retard or entirely prevent epidemics of diseases and parasites in game.

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THE NUMBER OF WATERFOWL AND THE KILL ON THE CHIPPEWA NATIONAL FOREST, 1937

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The method used in taking the waterfowl brood census on the Chippewa National Forest, Minnesota, essentially the same as that outlined on pages 139-a to 139-g of the Forest Service Wildlife Handbook for the North Central Region, is described in brief in the following paragraphs:

Ten per cent of the total shore line on the forest was selected for the census This included ten per cent of the Class II, III, and IV lakes (see below), as well as the potholes, creeks and rivers. The limnological classification of lakes on the Chippewa National Forest had already been made on the basis of intensive surveys conducted jointly by the University of Minnesota, the Department of Conservation and the Forest Service. Class II lakes are, in general, large, shallow and windswept; the bottom is often sandy; there is no thermocline; the wall-eyed pike is the predominant animal indicator, and productivity is high. Class III, or eutrophic lakes are usually smaller and deeper than Class II lakes; the bottom is often muck or marl; a thermocline is present, and the animal predominants are large-mouth bass, panfish, and great northern pike. Class IV, or dystrophic lakes, are usually small and shallow with a boggy shore line; this type of lake is approaching a terrestrial climax; the bottom is mucky, the water very warm in summer and the fish predominants are bullhead, carp, and mud minnow. The lakes and streams were carefully selected for a representative sample of all the types of breeding areas on the Forest.

Broods and adults were counted between daylight and 9:00 A.M. or between 5:00 P.M. and darkness, as during the hot part of the day the ducks sought shelter and were hard to flush. A canoe was used and each census area was covered by paddling as close to shore as possible, completely around each area. The smaller potholes were inspected by walking around them and hip boots were used in order that dense areas of cover could be examined. Binoculars were employed at all times to identify the ducks seen. All broods were tallied and a record kept of the number per brood when it was reasonably certain that all of the brood was visible. Females which had succeeded in hiding all but one or two of their brood, and those which exhibited maternal reactions were tallied as maternal ducks and assigned the average number of young determined later by an average of the brood counts. All other females and adult males were tallied merely as adult ducks.

Each lake, stream, or pothole was completely censused at one continuous paddling so as to eliminate the possibility of counting any broods twice. A small outboard motor was used on some of the unproductive lakes where there was no cover along shore in which the ducks could hide.

Census

Two preliminary surveys were made

for the purpose of determining the most desirable time to start the census. On June 23, Mud Lake was visited and although a few broods of mallards, pintails and ring-necked ducks were observed, it was quite evident that the majority of the ducks were still nesting. The preponderance of males among the ducks observed also proved this point. On July 2 a trip was made to Leech Lake east of Bear Island and although one nest containing eight eggs of the redhead duck was found, there were in sight five broods of ring-necked ducks, one brood of redheads, and three broods of mallards. Most of the young mallards were getting quite large and it was feared that if the census were delayed much longer, it could not be finished before some of the young mallards would be able to fly.

Accordingly, the census was started on July 6 beginning at the southern end of the forest and working northward until it was finished on July 26. The entire census was taken by the writer excepting on seven small bodies of unproductive water. Technical Foremen Floyd Colburn and Sigurd Dolgaard assisted on these areas and saw only one golden-eye on all seven potholes.

Table 1 shows the percentage of the shore line on census areas as compared to the total shore line on the forest:

Results of the census are shown in the following tables by classes of lakes and streams:

The number per brood, as recorded in Tables 2 to 7, was taken from actual brood counts during the census, averaged without regard to age classes. An attempt was made, however, to segregate broods by three age classes, namely, under two weeks of age; from about two weeks up to one-half grown; and over one-half grown. A record was kept of these three age classes during the census and they were then averaged along with brood counts taken before the census was started. By the time field observations were under way most of the mallards and teal had passed the first age class so not enough figures were available to give a good average for that group in those species. Forty-eight golden-eye broods were seen but as five of these had totals of 53, 46, 41, 33, and 29 ducklings, respectively, with only one female per brood, no satisfactory average could be made.

Brood averages for four species are shown in Table 8 by age classes.

TABLE 1
SAMPLE PERCENTAGE OF CENSUS

Class of Lake	Miles of Total Lake and Stream Shoreline on the Entire Forest	Miles of Shoreline in Census Areas	Percentage Covered by Census	Total Acreage of Water on Entire Forest
Class I	0	0	0	0
Class II	334	33.4	10	182,687
Class III	705	70.8	10	73,587
Class IV	174	17.5	10	19,636
Potholes	236	23.6	10	8,302
Rivers	188	22.0	11.7	0
TOTAL	1,637	167.3	10.2	284,212

TABLE 2

CENSUS RESULTS ON CLASS II LAKES

Species	Maternal Females		Average Number in Brood by Species	Total Number of Young by Species	Adults Other than Maternal Females	Total by Species on Census Areas	Calculated Total by Species on Entire Forest[1]
	Without Broods	With Broods					
Mallard	22	22	5.45	240	33	317	3,170
Blue-winged teal	4	3	6.66	47	23	77	770
Baldpate	2	5	7.00	49	3	59	590
Ring-necked duck	—	5	7.60	38	17	60	600
Golden-eye	3	16	9.20	175	43	237	2,370
Redhead	2	—	4.00	8	16	26	260
Hooded merganser	—	—	—	—	8	8	80
Black duck	—	—	—	—	1	1	10
TOTALS						785	7,850

TABLE 3

CENSUS RESULTS ON CLASS III LAKES

Species	Maternal Females		Average Number in Brood by Species	Total Number of Young by Species	Adults Other than Maternal Females	Total by Species on Census Areas	Calculated Total by Species on Entire Forest[1]
	Without Broods	With Broods					
Mallard	12	7	5.85	111	15	145	1,450
Blue-winged teal	1	8	7.25	65	2	76	760
Wood duck	—	1	8.00	8	1	10	100
Ring-necked duck	1	—	7.87	8	2	11	110
Golden-eye	2	10	13.90	167	21	200	2,000
Hooded merganser	—	1	6.00	6	7	14	140
American merganser	—	1	—	18	—	19	190
TOTALS						475	4,750

[1] Multiplying factor, 10.

TABLE 4

CENSUS RESULTS ON CLASS IV LAKES

Species	Maternal Females		Average Number in Brood by Species	Total Number of Young by Species	Adults Other than Maternal Females	Total by Species on Census Areas	Calculated Total by Species on Entire Forest[2]
	Without Broods	With Broods					
Mallard	17	15	6.87	220	58	310	3,100
Baldpate	3	1	9.00	36	3	43	430
Pintail	1	—	6.00	6	1	8	80
Blue-winged teal	4	19	8.37	192	21	236	2,360
Redhead	4	6	4.00	40	31	81	810
Ring-necked duck	5	24	7.58	220	34	283	2,830
Golden-eye	1	4	8.25	41	16	62	620
Ruddy duck	—	2	5.50	11	—	13	130
Hooded merganser	—	—	—	—	2	2	20
TOTALS						1,038	10,380

TABLE 5

CENSUS RESULTS ON POTHOLES

Species	Maternal Females		Average Number in Brood by Species	Total Number of Young by Species	Adults Other than Maternal Females	Total by Species on Census Areas	Calculated Total by Species on Entire Forest[2]
	Without Broods	With Broods					
Mallard	6	4	7.25	73	—	83	830
Pintail	1	—	6.00	6	—	7	70
Blue-winged teal	—	1	7.00	7	—	8	80
Ring-necked duck	1	1	9.00	18	2	22	220
Golden-eye	—	4	10.00	40	7	51	510
Hooded merganser	—	1	8.00	8	1	10	100
TOTALS						181	1,810

[2] Multiplying factor, 10.

TABLE 6
CENSUS RESULTS ON RIVERS

Species	Maternal Females		Average Number in Brood by Species	Total Number of Young by Species	Adults Other than Maternal Females	Total by Species on Census Areas	Calculated Total by Species on Entire Forest[3]
	Without Broods	With Broods					
Mallard	5	5	7.40	74	35	119	1,012
Baldpate	4	1	7.00	35	2	42	357
Pintail	—	—	—	—	2	2	17
Blue-winged teal	13	18	8.66	268	12	311	2,644
Wood duck	—	1	8.00	8	2	11	94
Ring-necked duck	1	—	7.87	8	—	9	77
Redhead	—	—	—	—	14	14	119
Golden-eye	2	3	9.33	47	4	56	476
TOTALS						564	4,796

TABLE 7
CENSUS TOTAL FOR ALL CLASSES OF LAKES AND RIVERS

Species	Maternal Females		Average Number in Brood by Species	Total Number of Young by Species	Adults Other than Maternal Females	Total by Species on Census Areas	Calculated Total by Species on Entire Forest
	Without Broods	With Broods					
Mallard	62	53	6.23	718	141	974	9,562
Black duck	—	—	—	—	—	1	10
Baldpate	9	7	7.50	120	8	144	1,377
Pintail	2	—	6.00	12	3	17	167
Blue-winged teal	22	49	8.15	579	58	708	6,614
Wood duck	—	2	8.00	16	3	21	194
Redhead	6	6	4.00	48	61	121	1,189
Ring-necked duck	8	30	7.68	292	55	385	3,837
Golden-eye	8	37	10.44	470	91	606	5,976
Ruddy duck	—	2	5.50	11	—	13	130
American merganser	—	1	18.00	18	—	19	190
Hooded merganser	—	2	7.00	14	—	34	340
TOTALS						3,043	29,586

[3] Multiplying factor, 8.5.

TABLE 8
AGE CLASSES OF BROODS

Species	Up to 2 Weeks Old	Number of Broods Averaged	2 Weeks to Half-grown	Number of Broods Averaged	Over Half-grown	Number of Broods Averaged
Mallard	—	—	6.31	19	6.54	37
Blue-winged teal	—	—	8.50	20	7.50	22
Ring-necked duck	9.15	20	6.55	18	—	—
Redhead	6.00	2	4.00	4	—	—

The apparent slight increase with age of the mallard broods probably can be explained by the fact that the young are very adept at hiding and that the counts, therefore, are not strictly accurate. Evidently, the loss in mallard broods occurs during the first two weeks because several nests with from 10–13 eggs recorded last spring had a 100% hatch.

Figures from Table 8 were not used when calculating brood averages for the census. Another year or two of more intensive study will be necessary before accurate averages by age classes can be determined.

Table 9 shows the average number of ducklings per brood for lake and stream populations regardless of age classes.

It is apparent from this data, provided the age classes average satisfactorily for each type of lake, that the highest mortality is on Class II lakes. This may be due to the greater numbers of large fish, turtles, and crows on this class of lake. On Class IV lakes where the brood average is high there are usually no fish of large size and cover is abundant.

In reviewing the census data by lake classes, the most noticeable feature was the apparent lack of ducks in the potholes. Figure 1 illustrates this point very clearly. Potholes as considered in this census were all bodies of water which were not named on any map of the Chippewa Forest. They ranged in size from one acre up to 100 acres but averaged 20.1 acres for a total of 413. Potholes which approached 50 acres or more in size and which had suitable food and cover and a low grassy or brushy shore line were productive but a greater proportion of potholes with little or no cover and a heavily timbered shore line brought the average down, In addition, potholes are hard to census accurately. When the census-taker approaches these small bodies of water he is visible to all its inhabitants

TABLE 9
BROOD SIZES ON VARIOUS CLASSES OF LAKES AND ON STREAMS

Species	Class II Lakes	Class III Lakes	Class IV Lakes	Potholes	Rivers
Mallard	5.45	5.85	6.87	7.25	7.40
Blue-winged teal	6.66	7.25	8.37	—	8.66
Ring-necked duck	7.60	7.87	7.58	—	—

and in the case of mallards this is enough to cause the duck to take her young far up on shore and into the woods. This difficulty may account in part for the low population figure for potholes.

had a dense growth of cattail, sweet flag, bulrush, and sedge along shore and in shallow water throughout its extent.

Table 10 shows comparative abundance between species as well as totals on census areas.

TABLE 10
COMPARATIVE ABUNDANCE OF SPECIES

Species	Total on Census Areas	Total Estimate for Forest	Comparative Abundance in Percentage
Mallard	974	9,562	32.00
Blue-winged teal	708	6,614	22.00
Golden-eye	606	5,976	20.00
Ring-necked duck	385	3,837	13.00
Baldpate	144	1,377	5.00
Redhead	121	1,189	4.00
Hooded merganser	34	340	1.00
Wood duck	21	194	1.00
American merganser	19	190	1.00
Pintail	17	167	0.50
Ruddy duck	13	130	0.50
Black duck	1	10	—
TOTALS	3,043	29,586	100.00

Class IV lakes, which comprise only one-eighth of the total shore line on the Chippewa Forest, had more than one-third of the ducks and were the most productive. The best of these ranged from 100 to 200 acres in size and were completely surrounded by a floating bog shore line covered with sedge and contained much coontail, bladderwort, duckweed, and some wild rice. Another productive type of lake was represented by one known as Ten Lake, which had nearly dried up in 1936. This year, ample water was present and the lake

Another significant occurrence brought out by the census was the surprising abundance of baldpates, a species heretofore considered as a rare breeder in Minnesota. On this census,

TABLE 11
TOTAL WATERFOWL ESTIMATES

Class IV Lakes	10,380 ducks
Class II Lakes	7,850
Rivers and Streams	4,796
Class III Lakes	4,750
Potholes	1,810
TOTALS	29,586

seven females with entire broods were counted and nine more either acted maternally or had one or two young with them. The estimate of 1,377 baldpates for the entire forest places this species fifth in abundance. Identification of the baldpates was easy and positive as the females were the boldest of any species, often fluttering within 10–15 feet of the canoe in an attempt to lead the observer away from their young.

Redheads were found breeding in considerable number on Mud, Leech, and Winnibigoshish Lakes. No lesser scaup were seen during the entire census. The last ones seen in the spring were two males and one female on June 6 in Lake Winnibigoshish. No green-winged teal or shovelers were seen during the census although two shovelers and one green-wing were observed as late as June 23 on Mud Lake.

A few mallards of a brood seen on Pike Bay on July 26 were just able to fly while the female remained behind with two that could not quite get off the water. This indicates that the census was completed in time but none too soon.

Without doubt, a few broods were missed during the census and some females were still nesting. It is felt, however, that the census represents a fairly accurate count for the forest as a whole.

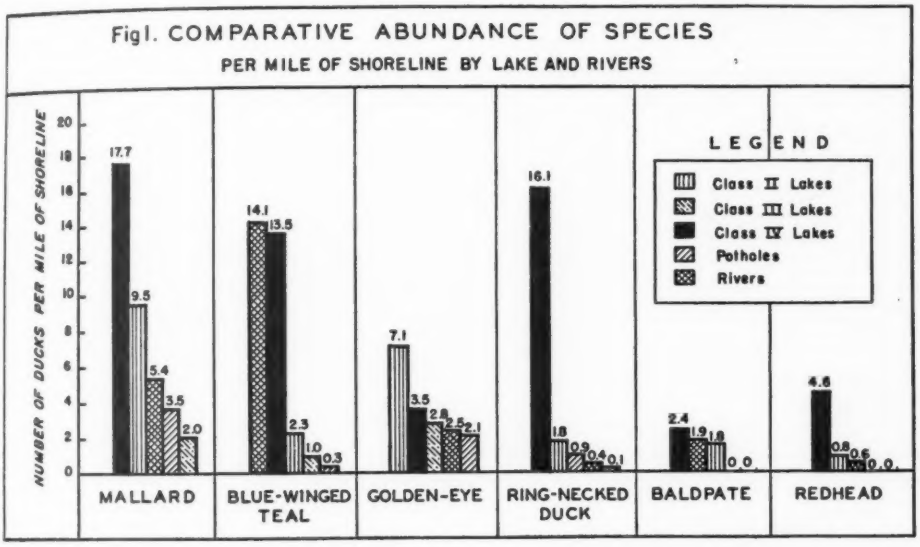

Fig. 1

HUNTING TAKE

In order to make an accurate check of duck hunting take on the forest during the 1937 open season six lakes were selected, representative of Class II, III, and IV lakes. These sample lakes included the wild rice type and the larger open-water lakes with wild celery beds which are so attractive to

bluebills. CCC enrollees under the supervision of forest officers were stationed at various locations so as to contact all duck hunters on each of the sample lakes and on every day of the hunting season. The CCC men assigned to the job were familiar with the more common species of ducks. The rarer species were identified when necessary by experienced men. Due to the difficulty of distinguishing between the fall plumages of the female ring-neck and lesser scaup ducks and to the large numbers of these species taken, all ring-necks and scaups were classified as "bluebills." Also, both green-winged and blue-winged teals were classified as "teals."

The total numbers of ducks actually shot and recovered on the six sample lakes are shown in Table 12. Crippling losses are not included; they would no doubt considerably increase the totals.

TABLE 12
ACTUAL KILL CHECKED

Kind of Duck	Name of Lake						Total
	Mud	Big Rice	Twin Lake	Cut Foot Sioux	Rabideau	Big Island	
	Class of Lake						
	IV	IV	IV	II	III	III	
Bluebill	67	245	43	654	109	131	1,360
Mallard	24	675	18	74	30	2	823
Teal	9	195	28	54	34	0	320
Pintail	3	111	0	0	0	0	114
Golden-eye	0	0	0	42	1	0	43
Gadwall	3	16	4	0	0	0	23
Shoveler	0	6	0	0	0	0	6
Ruddy duck	0	1	0	0	0	0	1
TOTALS	106	1,249	93	824	174	133	2,690

There is some question as to whether a number of the gadwalls listed were correctly identified; at least some of them probably were baldpates. Baldpates were much more abundant on the forest immediately prior to the hunting season and it seems that they should have shown up in the list of ducks shot; they may, however, have migrated. Here again the difficulty of distinguishing between the two species by enrollees and the hunters themselves affects the accuracy of the count as far as species go but does not affect the total number of ducks shot nor does it affect the numbers of the easily recognizable species such as mallards, teals, bluebills, and golden-eyes.

In order to estimate the number of ducks killed on the entire forest the actual kill by each class of lake was multiplied by a factor that was determined by dividing the total number of miles of shore line for each class of lake by the number of shore line miles actually checked. For example, of the Class IV lakes only 3 were actually checked with a total shore line length of 17.9 miles. On the entire forest there are 175 miles of Class IV lake shore line. $175 \div 17.9 = 9.72$, so by multiplying all ducks checked in Class IV lakes by 9.72, an estimate was arrived at for the entire forest. As no potholes were checked in the hunting take census the

total figure was increased by 16%, which is the percentage of the shore line of all the lakes represented by the shore line of all the potholes. The results of this final estimate are shown in Table 13.

TABLE 13
HUNTING STATISTICS

Kind of Duck	Actual Take on Checking Areas	Calculated Take on Entire Forest	Percentage of Hunting Take Compared to Brood Census
Bluebill	1,360	21,672	564
Mallard	823	10,119	105
Teal	320	4,218	63
Pintail	114	1,167	700
Golden-eye	43	985	16
Gadwall & Baldpate	23	259	18
Shoveler	6	67	None seen on census
Ruddy duck	1	12	9
TOTALS	2,690	38,499	130

Total number of hunters on checking areas..... 1,160
Total number of hours hunted..... 3,218
Number of man-hours to kill a duck..... 1.2

The 1937 duck kill was about 40% lower than the kill of 1936. Hunters were as numerous as ever the first few days but the number dropped off abruptly when it was found that the mallards and other puddle ducks were quite scarce. This scarcity was due to flooding out of wild rice beds and other duck foods by heavy rains and high water. Lack of food for the nondiving ducks caused them to avoid this section of the state; instead they visited the flooded grain fields in the northwestern part of Minnesota.

Actual take on four sample areas as compared with that for the same areas in 1936 is shown in Table 14.

Thus the actual take on identical areas for 1936 and 1937 showed a 53% reduction during 1937. The kill on Cut Foot Sioux Lake undoubtedly was lowered by the effect of three waterfowl refugees established close to the lake by the Minnesota Conservation Department in cooperation with the Forest Service.

TABLE 14
ACTUAL TAKE ON THE SAME AREAS IN 1936 AND 1937

Lake	Class of Lake	Actual Kill		Reduction of 1937 from 1936 Kill
		1936	*1937*	
Mud Lake	IV	771	106	87%
Big Rice Lake	IV	1,853	1,249	33%
Rabideau Lake	III	178	174	3%
Cut Foot Sioux	II	2,235	824	37%
TOTALS		5,037	2,353	53%

Percentages of the take by kinds of ducks from the four sample areas in 1937 as compared with those of 1936 are as follows:

	1936	1937
Mallard	43.5	30.6
Bluebill	36.6	50.5
Teal	13.7	11.8
Golden-eye	2.7	1.6
All others	3.5	5.5
TOTALS	100.0	100.0

It is evident from this tabulation that more mallards than bluebills were shot in 1936 while in 1937 the reverse was true. This is additional indication that the heavy rains and lack of wild rice had a definite effect upon the fall migration of mallards. Teals were also affected but to a lesser degree.

Ducks killed per mile of shoreline on the various checking areas were as follows:

Class II lakes—49
Class III lakes—38
Class IV lakes—81

This seems to indicate that not only do our Class IV lakes support the highest breeding population per mile of shoreline as earlier shown, but also that they yield the greatest kill of ducks per mile. When the number of man-hours needed to kill a duck is taken into account, however, it seems to indicate that the hunters had better success on the Class II and III lakes. The figures are:—

Class II lakes —.93 man-hours per duck bagged
Class III lakes—1.25 man-hours per duck bagged
Class IV lakes—1.36 man-hours per duck bagged

The concentration of hunters on Class IV lakes may be largely responsible for the comparatively poor man-hour average for that class of lake.

The kill during the open season exceeded the summer population by 30% or approximately by 9,000 ducks. Although the Chippewa Forest is for the most part an excellent breeding ground for waterfowl, especially during periods of drouth, nevertheless, these figures show that not enough local ducks are raised on the forest for resident hunters. The Canadian breeding grounds must furnish much of the bag. Any methods which can be employed to increase the number of ducks produced annually should be well worth the time and money spent on them and are necessary if the demands of the ever-increasing numbers of duck hunters are to be met.

SUMMARY

1. A complete waterfowl census was made on approximately 10% of each type of lake on each ranger district.

2. Optimum dates for census taking were between July 10 and July 20.

3. Young ducks seen without a female were counted as one brood and were assigned the average brood count the same as if the mother had been seen. All adult ducks were recorded.

4. Potholes were found to be low in production of ducks.

5. Mallards were most adept at concealing young.

6. Class IV lakes produced over one-third of all ducks but represented only one-eighth of the nesting shore line on the forest. Lakes of 100 to 200 acres in size seemed to be the most productive.

7. Baldpates were surprisingly abundant. No lesser scaup, shoveler, gadwall, or green-winged teal were seen on the census.

8. Kill records were obtained on six lakes, a 100% count being made by checking during the entire open season.

9. Bluebills (including ring-necked duck), mallard, and teals were most important.

10. The 1937 total kill was 53% lower than the 1936 kill due in part at least to a change in feeding grounds during the flight.

11. The hunting take was 30%, or approximately 9,000 ducks greater than the summer population.

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FISH BIOLOGY AND LIMNOLOGY OF CRATER LAKE, OREGON

Arthur D. Hasler[1]

Geologists tell us that some 20,000 years ago a magnifient peak, probably quite similar to Mt. Rainier, Washington, towered about 9,000 feet above the surface of what is now Crater Lake, Oregon. The last eruption of that old volcano exploded so forcefully that in a series of pumice flows, a huge void was created in the subterranean base of the mountain, into which the peak, without support, subsequently collapsed. The result of the collapse was an inverted cone, a volcanic caldera which in the years that followed filled with water to a depth of 1,996 feet.

In most places the shores of Crater Lake rise as sheer cliffs 500–2,000 feet above the lake surface. Only one good trail leads from the rim to the lake edge. The angler or sightseer who wishes to reach the lake must descend this 1.5 mile trail which zigzags along the crater wall.

Crater Lake has a surface area of 21 square miles. The elevation at the surface is 6,177 feet above sea level. Yearly precipitation is approximately 60–70 inches; consequently the lake level remains fairly constant. There is no inlet or outlet. The water is extremely soft. Van Winkle and Finkbinder (1913) gave the analysis of the water as 80 p.p.m. of solids; bicarbonates, sulphates, and chlorides were the dominant constituents.

The unusual transparency of the water, in addition to its apparent blue color, is very attractive. Observations of the Secchi disk (like a white dinner plate) suspended below the surface on a cord show how remarkably transparent is the water. The disk was visible 36 meters (118 feet) below the surface on August 10, 1937; at 39 meters (128 feet) August 19, 1937; and at 40 meters (131 feet) August 27, 1937. Kemmerer, et al (1924) observed the disk at 27 meters (82 feet) September 5, 1913.

A maximum summer surface temperature of 63.6°F. (17.6°C.) was recorded August 10, 1937. The minimum was 47°F. (8.3°C.) July 2, 1937.[2] The last seasonal reading was 55°F. (12.7°C.) September 3, 1937. Kemmerer et al recorded a surface temperature of 52°F. (11.1°C.) August 1, 1913. Figure 1 shows that definite thermal stratification existed in the summer of 1937. This figure illustrates very well the constant temperature of the water in the lower regions (hypolimnion), which comprise more than three-fourths of the volume of the lake. A temperature of 39.5°F. (4.1°C.) was read at 985 feet (300 meters) in 1937. Kemmerer et al recorded 38.3°F. (3.5°C.) between 985 and 1,970 feet (300–600 meters) in 1913.

It is an interesting experience for an observer who has worked on shallower North American lakes to make tem-

[1] Ranger Naturalist at Crater Lake National Park, summer, 1937.

[2] Crater Lake seldom if ever freezes over entirely.

perature readings with a deep sea reversing thermometer at these great depths. An uncanny feeling is imparted by the tick of the messenger as it slides down and down the calibrated rope until it trips the thermometer. The writer noted on one reading at 120 meters that the messenger was 27 seconds on the way.

BIOLOGICAL OBSERVATIONS

The most startling biological finding at Crater Lake was the collection, by dredge, of green mosses, *Fontinalis* and *Drepanocladus*, at the astonishing depth of 394 feet (120 meters). At depths of 60–200 feet, near Wizard Island, these mosses form a mat sufficiently thick to prevent the passage of a 6 inch Ekman dredge through the "weeds" to the bottom. This plant growth evidences the exceptionally deep penetration of sunlight in Crater lake. Juday (1934) reported these two genera of mosses at a depth of 20 meters in Crystal Lake, Wisconsin.

The growth of green plants at 120 meters seems quite unusual for fresh water. The writer was unable to find any reference in the literature to similar findings for any other lake in the world.

1. *Food of fish*

Brode (manuscript 1936) made a study of the stomach contents of trout and silverside salmon from Crater Lake. He examined 224 fish and expressed the results volumetrically. He found that 39.8% of the total volume of the stomach contents of all of the fish was composed of 2 crustaceans, *Daphnia* (33.5%) and *Hyalella* (6.3%). Caddis-flies and midges formed 26.9% of the total volume (this included caddis-fly cases which, of course, have little nutritional value, yet they make up the bulk of each capture). Snails constituted 9.4%; small fish and salamanders 19.7%, and miscellaneous groups 4.2% of the total volume. These facts show quite clearly that the fish

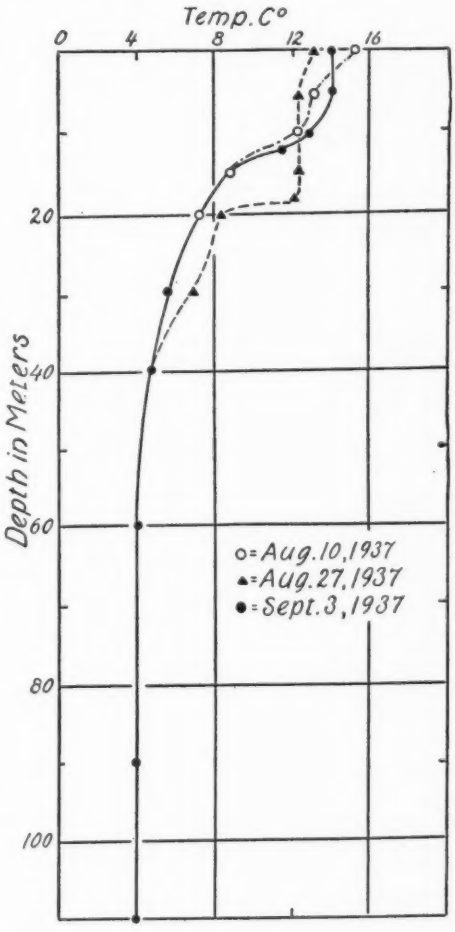

Fig. 1. The horizontal lines represent temperature in degrees centigrade and the vertical line depth in meters. Because the water at all depths greater than 100 meters was practically 4°C. the graph is concluded at 120 meters.

are pelagic feeders in the main and derive their chief nutriment from planktonic forms. *Daphnia* are very abundant in Crater Lake, but are specifically stratified in the deeper water. They occur most abundantly from 164 to 400 feet except near Wizard Island where they hover near the bottom of most of the bays at about 30 feet.

2. *Creel census from Crater Lake, July-August, 1937*

Many anglers have suggested that Crater Lake might be overstocked because of its reputation as a lake "where the limit can be caught with the least effort." To test whether this condition actually existed or was merely an opinion based upon various one-day catches, a creel census was initiated.

A CCC worker was stationed at the foot of the generally used trail leading out of the crater. As the fishermen returned from the lake their catches were enumerated and data collected as to length, weight, and sex of the fish. In addition, scales were taken from each specimen for age determinations. To augment these data, information was made available by the Crater Lake National Park Company, which operates the only boat concession on the lake, on the number of boats used, the time fished, and the cost of the angling to the fishermen.

Table 1 summarizes the data from this part of the investigation. The excellent angling return per man per hour fishing was 0.84 fish in July and 0.66 fish in August, 1937. Needham (1937) reported from a California lake (Convict Lake) a unit effort return of 0.21 trout. Fry (1937) reported a catch per unit effort of more than 1 lake trout in Lake Opeongo, Canada.

The data in the table do not include any record of a few early morning and late evening catches nor of fish caught by local anglers who scaled the crater walls at a rather low place on the rim called the "Wine Glass." The accessibility of the lake from that point is poor and it was the opinion of the rangers that very few fish were taken in that locality.

The unit effort record might be raised if it could be estimated how much time each fisherman spent in rowing to the fishing grounds near Wizard Island (1.5 miles from the boat landing). Most of the fishing is done in that locality by trolling with spinners.

This concentration of fishing within about a fifth of the lake area is a problem in maximum utilization of the fish

TABLE 1

1937 CREEL CENSUS FROM CRATER LAKE

Month	No. of Boat Reports	No. of Anglers	Total Fishing Hours	No. of Fish Taken	No. of Fish per Hour per Angler
July	317	721	920	767	0.84
August	318	666	794	535	0.66

Additional:	July
Average hours fished per boat:	2.8
Average length of trout:	16.4 inches
Average length of salmon:	16.1 inches

resources. The writer suggests two methods to extend the fishing area: (1) Furnish means by which the fishermen can be carried to more distant points in order to distribute the angling over a larger area; and (2) Encourage deep water fishing. The average fisherman never trolls deeper than 25–50 feet, usually near the Wizard Island. To judge from the habitat (164–400 feet) of the *Daphnia* which form the bulk of the fish food, it would appear logical to introduce deep trolling with copper line. At the suggestion of the writer one group of men fished at 200 feet. They caught silverside salmon which were in excellent condition.

3. *Growth rate of rainbow trout and silverside salmon*

Rainbow trout or steelheads (*Salmo irideus*) and silverside salmon (*Oncorhyncus kisutch*) were the only species identified during the summer of 1937. Scales from 300 fish were collected from the anglers' catches for age determinations. Of this group it was possible to determine age from scales of 275 fish: 124 trout and 151 salmon.

The scales were cleaned and mounted in Karo syrup on microscope slides. They could be readily observed under the microscope or with the Van Oosten projector.

Age of fish is recorded in the tables according to the method of Hile (1936). "During the first year of its life the individual is a member of the 0 group, during the second year of life it is a member of the I group, etc. Fish hatched in the same year belong to the same year class, regardless of their age at the time of capture."

Readings of the annuli and measurement of the anterior radius of each scale were recorded without reference to the original data in order to reduce personal error to a minimum. Subsequently computations of length at the end of each year's growth were made for each fish.

Table 2 summarizes the data for the actual lengths of the rainbow trout and places them in age groups, giving the calculated lengths at the end of each year of life. In addition, standard de-

TABLE 2

CALCULATED STANDARD LENGTHS IN INCHES ATTAINED BY VARIOUS GROUPS OF RAINBOW TROUT AT THE END OF EACH YEAR OF LIFE, AND THE NUMBER OF INDIVIDUALS COMPRISING EACH AGE GROUP

Age Group	Mean Standard Length	No. of Specimens	Average Calculated Lengths at End of Each Year of Life						
			1	2	3	4	5	6	7
VII*	26.5	1	2.6	5.5	10.8	14.6	19.0	23.0	26.0
VI		0							
V	19.7±1.3	9	2.7	6.0	10.9	14.4	18.7		
IV	17.3±1.8	56	2.8	5.7	11.2	16.1			
III	15.9±2.9	49	3.6	8.2	13.8				
II	13.6±2.2	9	4.6	9.5					
		124							
Average length in inches			3.7	7.3	11.7	15.3	18.7		
Increment of growth			3.7	3.6	4.4	3.6	3.6		

* Not included in average for calculated lengths.

viations from the mean standard length of each age group were computed. Increment of growth also is tabulated. Figure 2 presents these data graphically. The growth curves are practically linear functions and therefore indicate good growth under favorable feeding conditions. McCay and Tunison (1937) raised four species of trout under identical optimum hatchery conditions. Their rainbow trout that correspond to group III at Crater Lake were 7-14 inches in length. Their fish weighed 14.2 ounces at the end of 160 weeks. The average weight of Crater Lake rainbows at a comparable age was 23.7 ounces (see fig. 2).

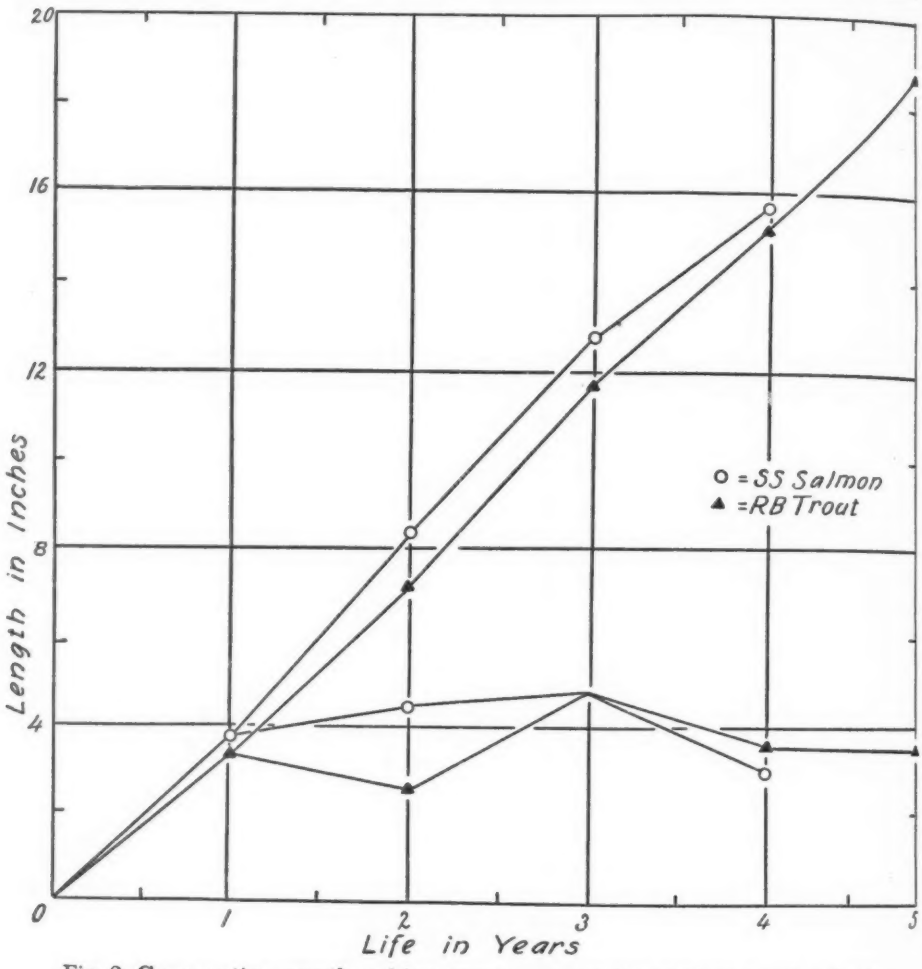

Fig. 2. Comparative growth and increment curves of 124 rainbow trout and 151 silverside salmon from Crater Lake, Oregon.

Hazzard (1935) studied the growth of rainbow trout in a western high altitude lake (Fish Lake, Utah). The fol-

lowing comparison of those fish with Crater Lake trout shows close agreement.

Years of Life	Fish Lake, Utah	Crater Lake, Oregon
1	2.9 inches	3.7 inches
2	7.5 inches	7.3 inches
3	12.4 inches	11.7 inches
4	15.4 inches	15.3 inches
5	17.6 inches	18.7 inches

Hazzard described Fish Lake as "exceptionally productive." We might say that Crater Lake fish, on the basis of these comparisons, also grow very rapidly.

The largest fish caught (see table 2) weighed 7 lbs., was 26½ inches long, and was beginning its 7th year of life.

Our preliminary studies of the distribution of *Daphnia* in the main body of the lake show that these organisms are restricted to that stratum of water between the 150 to 400 ft. levels. This means that the 150 ft. stratum above this area is devoid of fish food during the months of July and August. There are 1,600 ft. of water below the productive layer which like the top stratum are a desert as far as fish food production is concerned. Somewhat similar results were reported by Kemmerer et al. It is evident that the productive stratum of water is a relatively small proportion of the lake, indicating a limited food supply for the fish. In spite of this limited supply, the fish population is apparently well regulated with respect to the needs of fast growing fish. We might compare the lake with a sparsely vegetated sheep range which may produce a fat group of sheep if the feeding population is held to the proper number.

This conclusion must not be misconstrued to mean that planting of fish can be materially increased. Expanded stocking policy must proceed with caution, for the balance can easily be deranged if all conditions are not carefully watched.

In the discussion of the creel census, reference was made to maximum utilization of the lake resources. Here again it is emphasized that fish of excellent quality and in good condition might be caught in other localities than the vicinity of Wizard Island.

Silverside salmon showed more favorable growth in both length and weight (table 3) than the rainbow trout (compare Figures 2 and 3). The oldest sal-

TABLE 3
SAME AS TABLE 2, FOR SILVERSIDE SALMON

Age Group	Mean Standard Length	No. of Specimens	Average Calculated Lengths at End of Each Year of Life			
			1	2	3	4
IV	17.6±1.5	14	3.2	6.7	11.6	15.8
III	16.3±1.8	74	4.2	8.9	14.1	
II	14.6±1.3	61	4.0	9.0		
I*	5.3	2	3.6			
		151				
Average length in inches			3.8	8.2	12.8	15.8
Increment of growth			3.8	4.4	4.6	3.0

* Not included in average for calculated lengths.

mon collected were in their 5th year and reached a maximum average length of 17.6 inches. Just how much waste is connected with planting salmon cannot be estimated from our data but that there is considerable is indicated by shows that salmon in the age group II, weighed 1.21 lbs., while rainbows in the same group weighed 0.89 lbs. In other words they reach pan-fish size at an earlier age than rainbows. Figure 4 illustrates frequencies of the age

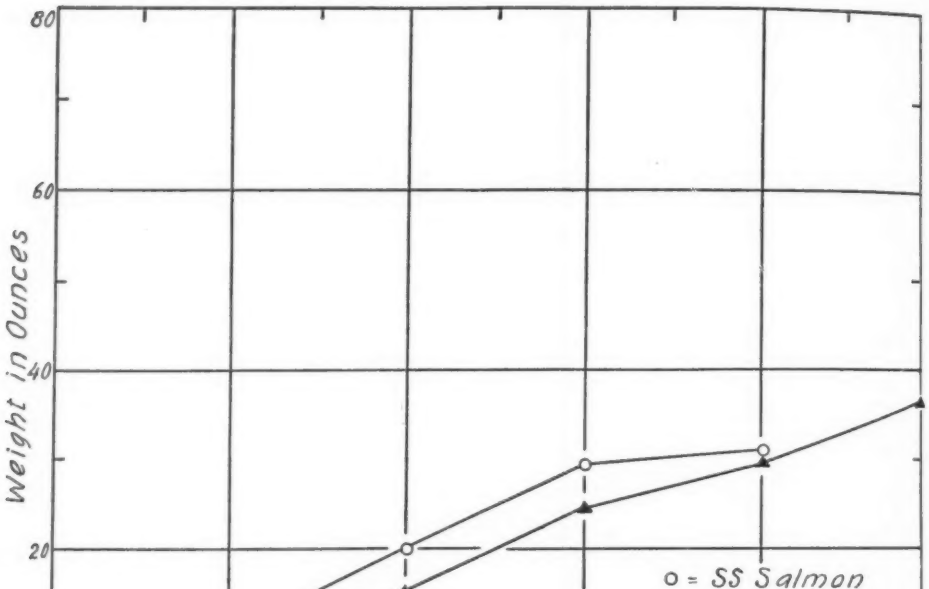

Fig. 3. Comparative weights of Crater Lake trout and salmon. Points indicate average weight for fish in each age group.

these landlocked salmon having the same 4 year life span as anadromous salmon that spend the major part of their life at sea. The loss by death of this species in Crater Lake must be large—just how large is a problem for the future.

There are certain advantages, however, to planting silversides. Figure 3 groups caught; it also indicates the superiority of silverside salmon. Forty-nine per cent of the 151 salmon examined belonged to age group II, while only 7% of the 124 rainbows were in this age group. It follows then that 7 times as many larger fish are catchable, by angling, from the younger salmon than from the corresponding

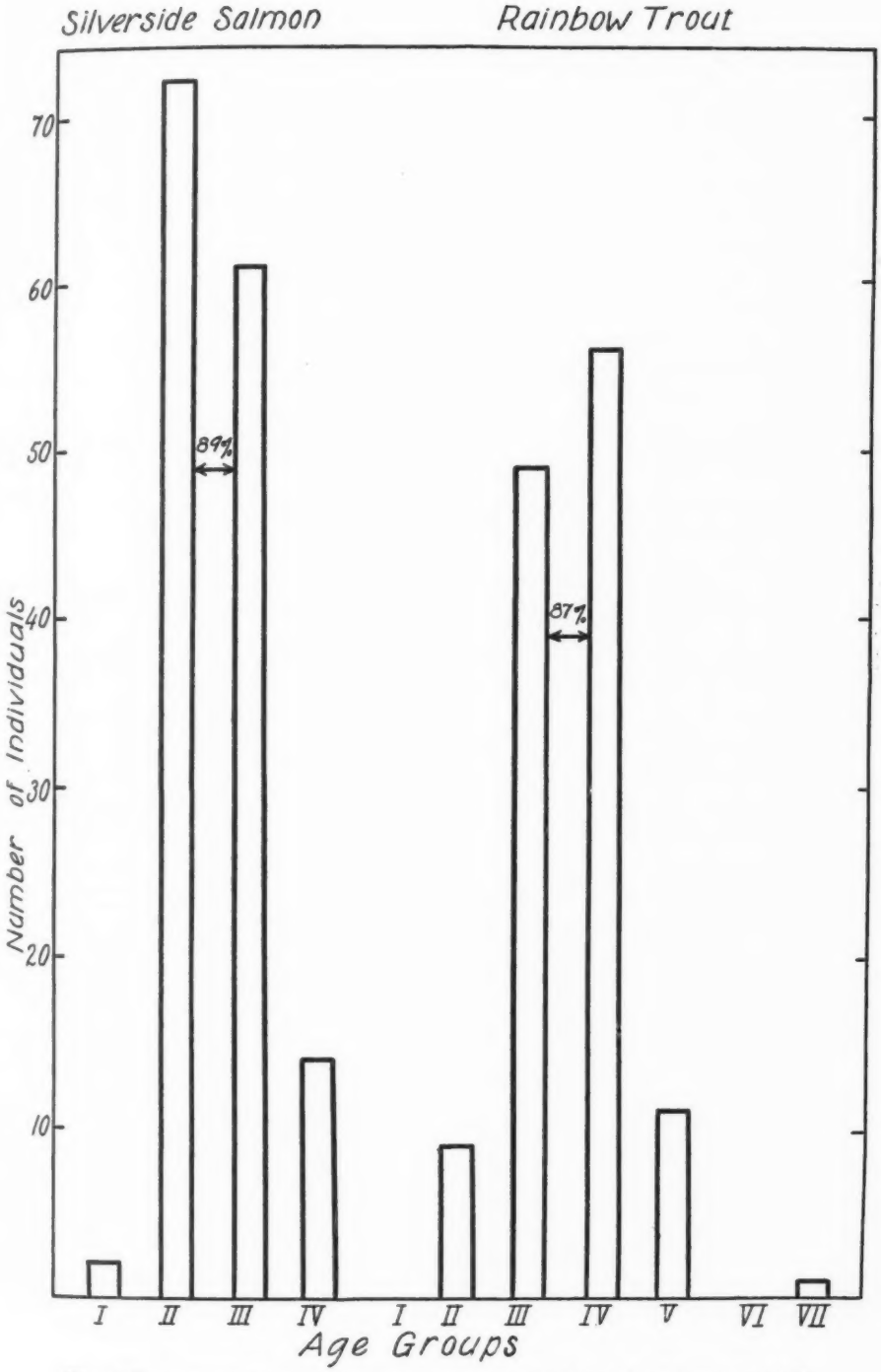

Fig. 4. Frequency distribution by age groups of 124 rainbow trout and 151 silverside salmon from Crater Lake.

age group of the rainbow population.

Restocking is dependent entirely upon artificial means as there is no evidence that either the salmon or trout develop naturally from spawn in Crater Lake. Whether this is due to lack of adequate spawning grounds, or to some other factor, is not known. The shoal area is not only very rocky, but the banks are precipitously steep.

It was of interest to note that 69% of all sexed rainbows were females, and that the same sex made up 67% of the salmon. Neresheimer (1937) points out that unequal distribution of sexes is not uncommon among hatchery stock.

The work here reported can be criticized because a single, possibly selective method of catch produced the specimens studied. Just how the growth curve would be altered if different methods of catch were used, such as fishing with various size mesh nets, may be determined in the future. The difficulties involved in procuring fish by this latter method, however, are evident from the character of the lake. The writer wishes to emphasize that this report includes only one season's study and is for this reason alone not entirely conclusive. It is hoped that investigations may continue and eventually lead to information which will govern a balanced scientific stocking policy. A careful management program based upon such studies should lead to a maximum use of the important recreational values inherent in the fish resources of Crater Lake National Park.

SUMMARY

1. A creel census in July 1937 showed a catch return of 0.84 fish per hour per angler, while in August it was 0.66 fish.

2. Green aquatic mosses were dredged from a record depth of 120 meters. The transparency of Crater Lake is indicated by visibility of the Secchi disk at the phenomenal depth of 40 meters. Definite thermal stratification existed in the lake during July and August 1937.

3. *Daphnia* are the leading food item of the fish, constituting 33% of the volume of food found in the stomachs.

4. Growth of trout and salmon in the lake is exceptionally rapid. Trout attain a length of 11.7 inches in the 3rd year of life. Silverside salmon are 14.1 inches in length at the same age.

5. Suggestions for proper fish management and maximum lake utilization are given.

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EXPERIMENTAL CONTROL OF SEXUAL PHOTOPERIODICITY IN ANIMALS AND POSSIBLE APPLICATIONS TO WILD LIFE MANAGEMENT[1]

Thomas Hume Bissonnette

In a series of papers beginning in 1925 Rowan (1) has shown that, for juncos and crows, increased lighting in autumn, to make the daily periods of light similar to those in spring, causes the sex glands of these birds to increase in size and in activity of their germ cells till the glands reach full breeding condition. Complete germ cell activity results at any time in autumn or spring between late November and the usual breeding season. He came to the conclusion and still maintains, however, that it is not the increased flux of light, as light, that acts upon the birds to increase their sex gland activity, but rather the longer daily periods of muscular exercise permitted or caused by the longer light periods that induce sexual or breeding activity and will do so in the absence of added lighting. Some poultrymen using night lighting were inclined to agree with Rowan, but on the whole they believed it was the additional time to feed, coupled with the shorter periods at night without feeding, that forced the added egg production resulting from such night-lighting with domestic fowl. At our suggestion they have studied this carefully and now agree it is the light that is effective.

[1] Aided by grants from the National Research Council, Committee for Research in Problems of Sex, 1930–1938, and by cooperation from the Connecticut State Department of Fish and Game, 1935–1938.

Starling Studies

Normal cycles

Between 1926 and 1933 the writer (2) studied the cycle of changes in the testes of starlings from November to May in collaboration with M. H. Chapnick, and from May to November alone with an eye also on changes in environment which might be closely correlated with the seasonal changes in the reproductive organs. This study was repeated to see if there were differences from year to year. Astonishing uniformity was found in the timing of the seasonal changes in different years despite quite different types of winter, spring, and summer, so far as temperature and barometric pressure were concerned. The only change in external factors that appeared to be uniform was the regular increase and decrease in daily periods of light and darkness. Even though this rhythm was slightly modified as the weather was cloudy or bright, it seemed the most probable causative factor for the physiological changes in the birds.

Suggested environmental modifying factors

In going over the literature it was found that Sharpey-Shäfer of Edinburgh in 1907 (3) had suggested, on purely theoretical grounds, in connection with migrations of birds, that this regular change in the relative length of

day and night was probably the effective factor concerned. He did not believe that change in the sex glands was the fundamental internal cause of the migration urge. Rowan (1) from his studies on migration, came to the conclusion that light, working through changes in daily periods of exercise and wakefulness, acted upon the sex glands of juncos and crows and that the changes in these glands and their activity caused the migration impulse.

Experimental control studies

We began our experiments in 1928 not fully convinced that Rowan's explanation and conclusions were right or the only ones compatible with his meagre data on the effects of exercise with juncos.

We adapted and improved his exercising cage for our use with starlings and began prolonging the daily period of light for one cage of starlings from December 4, increasing the night lighting fifteen minutes per night from the normal daylength for that date. We also used the exercise cage for similar periods each night for a second set of birds (exercise or work group), and a third group were without added lighting at night except for a three candle power light, at a considerable distance, shining almost equally into all three cages. This enabled the birds in the exercise or work cage to see the cross pieces on the moving belts, that swept clear the roost and floor every twenty seconds, so that they could avoid being caught and killed by them. The motor for the exercise cage and the lights for the lighted cage were on the same circuit controlled by the same switch (2).

Light vs. exercise

On January 4, after thirty-one days of experiment, birds from each of the three cages were sacrificed for study of their sex glands. Histological study and measurements of the testes of males showed conclusively that increased exercise reduced the size and activity of the glands slightly as compared with controls without forced increased exercise or light; whereas increased light from a 60-watt incandescent bulb, acting for equal periods, was very stimulating to the sex glands. This proved true at different times of the year provided the birds were not already activated. In a test of such birds, lighting time was reduced for two sets of starlings, one with and one without forced exercise. We found, as had Rowan with juncos, that in those with reduced lighting and without forced exercise the sex glands and their activity very quickly underwent regression. In those with added exercise but reduced light the testes increased in size and activity for a considerable time after reduction of lighting and then underwent regression, returning to the winter condition often at a more rapid rate than in the case of those without exercise, overtaking them in the later stages. Further experiments showed that added forced exercise given with added light to birds at or nearing the minimum of activity of sex glands caused them to lag behind those with added light but without forced exercise in undergoing increase of testicular activation and size. In this case also activation was subsequently accelerated and in later stages overtook that of lighted birds without added forced exercise.

It was therefore concluded that: (1) for starlings at least, and probably for other birds, changes of light up or down were the major activating or stimulating and retarding or inhibiting factors, and (2) added exercise acted merely as a modifying factor increasing or prolonging the refractory period elapsing before changes in length of day become effective in modifying the relative activity of the sex glands. From the similarity of the results of these experiments with forced exercise and reduced lighting to those of Rowan with juncos I was led to believe that the same factors were effective in that case also. Added exercise alone was not a stimulating factor for sexual activation for such birds. Subsequent studies by myself and others on birds, here and in Japan, England and France and on mammals, have confirmed this conclusion.

Intensity factor

Further studies, using light-bulbs of different luminous intensities, indicated that up to a certain optimum, but not beyond it, increase in luminous intensity of the light reaching the birds caused an increased rate of acceleration of activity of the sex glands of males. Fifteen-watt bulbs at similar distances and for similar daily periods were more effective than those of 10-watts and the progression continued with the ordinary wattages; it was found, however, that a 200-watt bulb at somewhat similar distance is more effective than one of 1,000-watts delivering much greater luminous intensity at the roost. It was determined that effects were due not to total energy delivered to the bird, as measured by a thermo-couple, but to luminous intensity, as measured by a photometer (4).

Wave-length or color factor

Experiments using filters to provide light from the red, the green, and the violet parts of the visible spectrum as well as unfiltered white light from electric bulbs showed that, for starlings, red light was very stimulating sexually at as low as 1.7 foot candles, while green and violet were not stimulating at all. White was intermediate between red and no added light and was effective probably in proportion to its content of the longer-waved red rays. Ultraviolet and infrared were not tried alone but were not necessary to the effects of white light and apparently did not add to its effectiveness. A sun-lamp was not as effective as an ordinary bulb yielding equal luminous intensity at the roost, probably because of less intensity at the red end of the spectrum (2).

Dietary deficiency

Improper diet lacking in fats, proteins, and vitamins inhibited the action of even red light of 2.2 foot candles intensity so that almost no activation of the testes occurred in birds restricted to it. While changes of food did not initiate sexual activation, improper food did prevent maximum effect of red light of proved potency.

Birds could be brought into complete sex-gland activity and size at any time of year and at any temperature found in nature here in winter or summer, by increased lighting, provided they were not already activated; and they could also be induced to delay activation or undergo regression by reduced lighting.

Temperature and barometric pressure were the same for all birds in each experiment, controls as well as experimentals.

Refractoriness and regression

Though added light was potent to induce sexual activation under all these conditions, it was noted that in nature all male birds underwent sexual regression, beginning in May, which was so far advanced by June 15 that no sperms were ever found in testes of birds autopsied on that date, though length of days and intensity of light by day increase normally till June 21, or even later for intensity alone. Under experimental conditions, increased lighting also brought birds to maximum activity but could not hold them there. They underwent regression after a time, even with increasing length of day, the time varying inversely as the strength of the stimulus needed to bring them into activity and directly as the time required to induce maximum activity. The quicker they were brought up, the sooner they regressed and *vice versa*. This regression did not appear to bear any relation to the increased content of green, violet, or ultraviolet in the light to which the birds were subjected.

Sex differences

With male starlings it was found that gradual increases in daily lighting were not necessary but that a sudden increase by six hours per night gave maximum and very uniform activation. With females the effect was neither so regular nor so great. Some were not much, while others were quite definitely affected. Females require regularly increasing light periods to be uniformly activated.

STUDIES ON MAMMALS

Ferret (normal cycle)

While on Sabbatical leave from Trinity College in 1931–32, I went to F. H. A. Marshall's Laboratory for the Study of Physiology of Reproduction, at Cambridge University, England, for the purpose of investigating the possible reactions of mammals to similar experimental changes in length of daily period of light. The ferret which had been studied thoroughly as to its sexual cycle in males by Miss M. Allanson (5) at London, and in females by Drs. F. H. A. Marshall (6) and Hammond and Marshall (7) at Cambridge, was selected as a favorable species for experiment.

Males become sexually active from February 20 or earlier and females from March 1 or later, and both sexes become sexually impotent from late August onward. No ferrets had ever been known to be sexually active in England at any other seasons except as the result of injections of gonadotropic hormones (7). Moreover, the female ferret does not ovulate spontaneously, but only some 34–40 hours after copulation, which is much prolonged in these animals, even up to three hours of fixation. The vulva of the female swells quite markedly when she comes into heat and both heat and this swelling persist throughout the summer unless copulation occurs, succeeded by pseudopregnancy or pregnancy lasting 42 days. This is again followed, after suckling, by a second heat period, mating, and pregnancy,

pseudopregnancy, or anoestrus in the same summer.

Ferret (experimental lighting)

Experimental lighting was begun on October 12, 1931, on three females and three males, with controls, in similar unheated rooms, in the animal house at Cambridge (9). On the basis that, for male starlings, an increase of daily lighting of six hours from the start was completely effective, light from a 200-watt bulb at convenient distance from all six cages was used for six hours each night in such a way that the animals could not hide from the direct light. This light was controlled by a time switch set to give these hours of electric light each evening from shortly after sundown onward. The period of electric lighting was not increased with decrease of day-length, so the actual hours of light per day were suddenly increased by six hours and then gradually fell off with the decrease in normal day-length till December 21.

This proved completely effective with experimental females, all three of which came into oestrus and received copulation from males similarly treated. Two were in full heat on November 23 (after 42 days of extra light) and the third was found to be hiding her head from the light. After reduction of her bedding she also came in heat on December 1. These females copulated with lighted males on December 11, 12, and 21, respectively. No sperms were recovered from their vaginae after copulation and all proved to be pseudopregnant.

Two of the original experimentally lighted males died on November 18 and 25, after 37 and 44 days of experimental lighting, respectively. Both showed some degree of activation, particularly of the interstitial cells of the testes, and one of the epididymus. The other male was sacrificed on December 22, after copulation with the last of the three females. His epididymus was in full breeding condition, as were also the interstitial cells of the testis. His libido was that of a breeding male and his copulation normal in behavior and length, up to three hours; but the testis tubules showed evidences of initial stimulation followed by regression of the germ cells, and no spermatozoa. Another male transferred from the control room to the lighting room showed willingness to mate and apparently normal breeding libido within two weeks of his transfer to the lighting schedule on November 25. Control males did not show sexual libido till February, and females came in heat only at the normal time in early March and April (9).

Female and male ferrets exposed to reduced lighting to the end of May by curtaining their cages to keep the number of hours of light equal to those of mid-winter were delayed in, but not completely prevented from, coming into sexual activity.

Subsequent modification of the manner of giving the light increases, stepping up the electric lighting period one hour each week to a maximum of six or even eight hours per night, in autumn, till December 21, and leaving it constant thereafter, has brought both sexes into complete sexual activity, potency, and libido, with fertile matings, pregnancies occurring as early as November 27 and December 3, and a litter of young born on January 14. These experiments were carried out in

unheated rooms so cold that all the young died from exposure. Under normal lighting conditions the earliest litters recorded were from April 10, or later (10).

Avenue of reception

Experiments, using hoods, with and without eyeholes, as against controls without hoods, indicate that the eyes are the receptors for this sexual activation by increased lighting and not the bare skin of the face (10). The stimulus is received, however, by animals curled up in sleep with the eyelids closed. Severance of optic nerves frees the animals from the light stimulus. Ferrets thus operated on show an inherent rhythm of sexual activity and quiescence, however, although it is not correlated closely and adaptively with the seasons as in the case of animals with intact optic nerves (11).

Wave-length studies

Subsequent studies on the ferret by Marshall and Bowden (12) show that all the visible spectrum and a short contiguous part of the ultraviolet is apparently almost equally effective in sexual stimulation and that oestrus is prolonged in females subjected to ultraviolet. Some of our females, however, showed prolonged oestrus when brought into sexual activity earlier than normally even without ultraviolet (11).

Dependence on the hypophysis

Studies by Hill and Parkes (13) and ourselves (11) have shown that the hypophysis is essential to this type of activation. We have found that the anterior lobe cells undergo a cycle which parallels that of the sex glands and respond to light stimulation synchronously with the sexual cycle. Pelage changes also appear to be correlated with this cycle of the anterior lobe of the hypophysis and, in the ferret, are subject to control by experimental lighting (10).

STUDIES ON DUCKS

Benoit's (14) studies have shown that ducks are sexually conditioned by length and intensity of daily light periods, that reds and yellows are the effective rays while greens, blues, and violets are not effective. He has shown that, in the absence of eyes, the optic nerve stump and even the hypophysis may be stimulated directly by light to give activation of the sex glands; but only when the thyroid is intact.

VARIATIONS IN RESPONSIVENESS

Cole (15) has obtained viable eggs from mourning doves by use of increased lighting, and Scott and Payne (16) have caused turkeys to lay in January instead of March or April, with red light effective, but not blue. If the light was added only in extra intensity during the day and not in added duration, there was no effect. Guinea fowl failed to respond to increased duration of daily lighting (17). Sparrows have shown slight variation from the reactions of starlings under similar treatment. The old males are refractory in early autumn but not later, while young ones are susceptible to light stimulation from early autumn onward (17). Guinea pigs (18) and ground squirrels (19) fail to show sexual photoperiodicity and sexual cycles of field mice (20) and hedgehogs (21) are modifiable by altered lighting and also

by changes in food and other factors, respectively.

Deer and sheep come into activity on a shortening day instead of a lengthening one and so do some fishes and other animals (27, 31, 32). Thus they respond to altered lighting in a way opposite to that of the animals previously discussed. The kind of response is correlated with duration of gestation period in both cases. Some animals are photoperiodic sexually in one way, some in another, and some apparently not at all. Each species shows its own peculiarities in this regard and until these peculiarities are known, control of breeding cycles will be guess work. Research on each species is needed to show where it stands in this respect (10, 11).

STUDIES ON GAME ANIMALS

Bobwhite

The first case of the use of alterations of daylength to induce early and prolonged reproduction in a game species that has come to my notice was carried out by Uel Petty in Oklahoma. He induced bobwhite quail to lay from January 1 onward in 1931, and from December 3 in another year, by increased lighting and controlled temperature, humidity, and food. Brill's account (23) mentions only the humidity, temperature and food control; but Mr. Petty himself, in answer to a question about lighting, tells that glow-lamps of sufficient luminous intensity to permit the birds to move about as at dusk were used at all times. The birds also received light from 50-watt lamps during enough hours each evening to give a period of light each day equal to that of daylight in the month of June. One hen laid 167 eggs. These birds were induced also to "group mate," two cocks to seven hens, and the resulting fertility was just as high as with pairs. Hatchability was good and growth of the young chicks better than normal. Bissonnette and Csech (24), by night lighting with a 60-watt bulb for three hours per night following daylight from December 16 to 26, four hours till January 6, and for five hours per night thereafter, induced bobwhites to lay outdoors at Hartford, Connecticut, from March 22, 1936, with fair fertility and some hatch, without control of temperature, humidity or food. That the hen used had been a poor layer even under normal seasonal light cycles and died in early June may account for her late start and the small number of eggs.

Ring-neck pheasants

Martin (25), using continuous electric light from 5:00 P.M. to 6:00 A.M. and feeding for egg production, from December 5, induced laying in ring-necked pheasants beginning on January 1, 1935. Cold weather did not hamper egg production, but no eggs were fertile during the first three weeks of laying. After that, fertility was high, especially after the days became warmer in late winter.

Clark, Leonard and Bump (26) in 1936–37 found that pheasants, quail and ruffed grouse all responded to increased illumination in winter by enlargement and activation of the sex glands, but they failed to continue the experiments long enough to secure laying. They may have used a single abrupt increase instead of gradual increases of lighting and this may account

for their females' failure to lay. They found that shortening the daily light period in spring prevented or greatly retarded these birds from becoming sexually active and breeding.

Albert G. Csech and I, with the cooperation of Arthur L. Clark, Superintendent of Fish and Game for Connecticut, began an experiment on December 16, 1935, to see if earlier eggs could be secured from pheasants and bobwhite. The hope was to get birds in full plumage long enough before the opening of the shooting season to permit them to be liberated early and become acclimated to their new range and wild enough to make good sport. The bobwhite experiment is described above. The hours of electric lighting for one cock and four hen pheasants were the same as for the bobwhite, namely three hours per night after normal daylight periods at the beginning, increased each ten days by one hour per night to a maximum of five hours and kept constant at that level until June 29, when the birds were returned to normal daylength. With two weeks of extra lighting the cock acquired breeding colors of the head furnishings and gave the mating call. The hens laid two eggs on January 15 and within ten days all four hens were laying fertile eggs. One hen died after laying about 35–40 eggs. The other three laid an average of 105+ eggs each, before June 29 when the experiment was terminated. The cock did not appear to be harmed by the forced sexual activity though he proved unsuccessful as a breeder the following winter. The hens all died sometime during the summer and may therefore have laid themselves to death. This indicates what a powerful stimulus the increased lighting may become and suggests caution in using it if hens are wanted for several years of breeding.

Pheasant spring chicks lay in autumn

A second experiment was carried out to see if pheasant chicks hatched at the usual time in spring could be induced to lay in the following autumn as do early hatched domestic fowls. One cock and five pullets, hatched on May 7 from eggs laid by the early layers of the previous experiment, were subjected to night lighting at 151 days of age. Normal breeding behavior began in all the hens and the cock but only one hen laid any eggs. She began on November 8 at 185 days of age, and laid eleven eggs. Of these, one was broken and ten were set. Five proved fertile and three chicks hatched on Christmas day (28). One of these was crushed by the hen; the survivors were pullets and in June they were placed with a mature cock without experimental lighting. Two eggs were laid on July 25 and 27, probably by the same hen (29), but neither was fertile, probably because the cock was past his effective breeding period.

Lessons for pheasant management

These two experiments demonstrate that pheasants of good laying stock are capable of breeding and producing fertile eggs in autumn but for the shortening of the days at that season, and that they can be made to do so by proper lighting. They show also that pheasant chicks hatched even as late as December 25 can lay in July following without experimental lighting, despite falling daylength from June 21 onward. The tests suggest, moreover, that pheasant

chicks hatched in November can lay in June and give a useful number of eggs before the shortening days in July reduce their laying performance, or they can be kept in production by short daily increases of artificial lighting beginning June 21 or earlier. Taking advantage of this possibility will greatly reduce the cost of keeping birds before they begin to lay and so lower the outlay for restocking areas for hunting. With early production by birds hatched in the early fall, planting can be effected also at almost any time of year,—a procedure which will yield more wild birds that have never been enclosed and dependent upon man.

Experiments on a larger scale this past year indicate that not all pheasants of either sex are good breeders, even under lighting stimulation, and suggest that selection may eliminate poor breeders and build up a strain of prolific layers as well as wild, nervous birds that make good hunting by taking to flight immediately on being disturbed (29).

Raccoons

Lighting experiments with raccoons have given startling results (30). Controls consisted of the colony of raccoons of various ages and both sexes at the Shade Swamp Sanctuary, Farmington, Connecticut, numbering over thirty animals, fed and housed in the routine manner. Their behavior and times of holing-up deviated in no respects from normal. Mating began in the first week of February and litters were dropped at the usual time. Only 40% of the females bore young, but only 25% had done so the previous year. Holing-up in December and January was normal and food consumption ceased for varying times during those months. Some females became "ugly" near term, some did not; some made nests for young but proved pseudopregnant; others had young but made no nests for them; but the majority of those having young made nests.

Three pens similar to those occupied by control animals were experimentally lighted in such a manner that both the den and the open runway were lighted by a 60-watt bulb set in an opening in the front wall of the den. One male and two females were confined in each pen. One female in each pen was known to have bred the previous year without experimental lighting. They had produced litters of four, three, and one young, respectively. The other female in each pen was known to have failed to produce a litter the previous year (one had a still-born foetus). This selection was made to determine whether experimental lighting would increase fertility as well as give earlier litters. Feeding and care were similar for all animals, with protein in the food ration built up to a 40–50 per cent level with fresh meat and fish added to a composite proprietary food. Lights were turned on by a time switch at 6 P.M. for one hour each night from October 10 to 17, two hours per night to October 27, three hours till November 6, four hours till the 17th, five hours till the 27th, six hours till December 7, seven hours till the 17th, and eight hours per night thereafter until the animals had to be separated because females were becoming "ugly" toward each other and toward the males.

The first deviation from normal behavior to be noted was failure of the

lighted animals to reduce food consumption and "hole up" in pseudo-hibernation in December. Matings began on December 16, 19, and 23 in the three cages, respectively, and each male mated repeatedly with both females in his pen for about a week and then appeared to stop. The animals then "holed up" for three or four days between January 20 and February 10 during a time of very heavy snow, with temperatures between zero F. and 6–8° below, each night. This was their nearest approach to pseudo-hibernation and even then they were active within the dens. Before January 28 the females began to be "cranky" and the males were finally driven from the dens and refused reentry. The animals were then separated. Experimental lighting was discontinued with some of the females and not with others, to see if continued lighting was necessary to proper gestation and suckling. All females built nests; so all were at first judged to be pregnant.

Litters of four, one, and three kits, respectively, came on February 27, and March 4 and 10 from the proved breeding females. The other or poor breeding female in each pen was only "pseudo-pregnant." The first female to litter and one of the others had their experimental lighting stopped before parturition, the other had not. All three suckled and raised their litters successfully. They were the females having litters the previous season under normal lighting, and had the same number of kits per litter as before. The known poor breeders evidently were incapable of having litters. It appears that fecundity was not altered by the extra lighting but only the time of mating and of having litters.

The kits grew faster than those born at the normal time and were larger in the autumn than their parents. They were large enough to have been liberated in late summer but were kept over.

After completion of suckling or "pseudopregnancy" all six females were returned to the same males. They mated again but this time all six were only "pseudopregnant." This second mating period for raccoons must be very rare as it does not occur in nature or on normal light cycles at this sanctuary and no controls exhibited it (30).

Effect of reduced protein rations

During last winter (1936–37) the same sort of experiment was carried out on a larger scale using thirteen pairs of raccoons as controls, without increased lighting, and nine pairs and four groups of one male and two females, with experimental lighting (30). One pair of controls and one of the experimentals were young raccoons born during the previous experiment. Lights were on for one and a half hours per night from October 19, three hours from November 29 and the period was increased by one hour per night each ten days to a maximum of eight hours per night on December 18. Experimental lighting was discontinued when females became "ugly" near term and was not resumed because in the previous experiment it was not found to be necessary for suckling and maternal care.

The proprietary "balanced complete ration" was again used in this experiment but without the build up of proteins used the previous year. It tested 21.19 per cent protein and was used till low productivity of the experi-

mental animals became evident. Food for both controls and experimentals was then altered so as to consist 40–50 per cent of protein as in the previous experiment. General care was the same as before and there was no heating of the outdoor pens.

Both control and experimental animals reduced their food consumption during late November and December, but only a few controls stopped eating and "holed up." This behavior was correlated with the mildness of the weather and lack of deep snow. None of the experimental animals "holed up" or stopped eating.

Controls mated as usual from the first week of February onward; experimentals from December 15 to January 5 or later. Not all experimentals or controls were seen to mate but many were and their behavior leads us to believe that all did so. Both young pairs born early from the previous experiment were seen to mate repeatedly. Mating in their first winter often occurs with young raccoons born at normal times and not experimentally lighted but pregnancies seldom result.

On the "low protein" diet, litters produced by controls fell to 23% (3 out of 13 females) from the 40% in 1936 and 25% in 1935 yielded by animals on the higher protein diet. Experimentally lighted females having litters fell to 41% (7 out of 17 females) from the 50% of 1936. These reductions in the percentages of females having litters in both controls and experimentals occurred despite the elimination of all known poor breeders from this experiment, and the premeditated selection of 50% non-breeding or poor breeding females in the 1936 experimentally lighted group. While the reductions were not large they brought the number of females having litters far below the expected numbers. The increase of protein in the rations came too late to help either group, as matings were already past.

Only one of the three females which gave litters in 1936 from early matings, repeated this year. The other two were only "pseudopregnant." Neither the control nor the experimental pair of early-born raccoons gave litters in their first winter. But, of three females and two males in a single litter, born at the normal time in spring, 1936, and kept together in an exhibition pen without enclosed den, two of the females became pregnant and bore a litter of two each, a little later than the normal time. They received more daylight during the day than our controls and this may account for their first year litters. One deserted her offspring, however, before being moved to a pen with a den and the other suckled only one.

Two litters in one season

On return of the experimentally lighted females to pens with the same males as before, but without experimental lighting, many, if not all, went through a second period of matings after completing either "pseudopregnancy" or weaning their young. As the result of these second matings four litters were born between July 28 and August 18. One of five was from a female that was only "pseudopregnant" at the first mating-period in December. The other three were from females having litters from the first matings. These two litters per season from

some of the raccoons are the most remarkable results of this experiment.

With reduced protein diet for the early part of the experiment, abandoning litters or eating them was somewhat more prevalent this year than is common but it cannot be attributed entirely to the low protein because it occurs in nature and on adequate diets even as late as at six weeks in suckling. Nor was it the result of disturbing the litters. None of the females having litters from the second matings abandoned or ate the young; all were successfully raised.

The early first litters again grew better than normal and were released into the wild in August. This achievement shows the possibility of cutting the cost of raccoons for liberation as those born at usual times have to be kept until late autumn or even over winter before liberation. The second litters will be ready for liberation this spring, and, since they were born later than usual, the cost of their keep in captivity is reduced.

Cottontails

Unpublished experiments on cottontail rabbits give evidence that the sexual cycles of these animals are also amenable to modifications by increased lighting and that sexual activity may be obtained in winter. The tendency of the females activated in this way to kill the males when in close enough confinement to make lighting effective, or of an occasional male to kill the female of the pair so confined, however, has led to difficulties not yet surmounted. Males have had their sex glands activated to sperm production in winter. Females have built nests and lined them with fur in winter but no litters have yet been born out of normal season, for the reasons given above. More than that, if young had been born in the unheated pens, they could not have survived because the parents do not keep them warm, but leave them in the nests for long periods when the young are too unprotected to keep themselves warm. If success in increasing winter production of this species is to be attained it must involve some way of preventing the fatal strife between prospective parents and of providing an artificially heated place for the nests to receive the young and keep them warm.

FISH EXPERIMENTS

Hoover and Hubbard, of the New Hampshire Fish and Game Department, have carried out some significant experiments on brook trout, which are autumn breeders and spawn on a falling daylength (31, 32). Sixty selected late-spawning fish, ripe in December, were placed in three aquaria (20 fish each) at the New Hampshire Hatchery and allowed till February 2 to pass an expected refractory period in the sexual cycle. All fish received the same care, water temperatures were uniform at an average of 7°C. (5–10°C.) with the same amounts of food to each aquarium, the ratio of volume of water to volume of fish was as nearly uniform as possible, and the water came from a common supply by a single pipe with an outlet for each aquarium. One group was run as control, without experimental modification of the daily light period. The other two groups (A and B) were exposed to an additional hour of lighting each week until eight hours

of light were added to that of the normal daylight period at Latitude 44°N. After four weeks at eight hours of electric lighting the additional light was gradually diminished in both aquaria until normal daylength was reached. From this time onward group A received the normal daylength of approximately 15.5 hours each day for four weeks (24–27th weeks of experiment) and then normal length of day began to decrease (28th week) with the approach of fall days. Group B, after the end of the 23rd week, was exposed to gradually reduced daily lighting by covering their aquarium with a lightproof box for increasing periods each day till their daily light period was only about seven hours.

Sampling was carried on and comparisons made of the gonads of fishes from all three aquaria with those of wild fish. Gonads of controls remained normal throughout the experiment but sex glands from both A and B groups (experimentals) were larger than those of controls during the later part of the experiment from May to August. On August 12, all males in tank A were sexually active and ejected spermatozoa copiously when stripped in the usual manner and females had distended vents. In tank B at the same time three out of ten males were "ripe" but it was not until some time before August 31 that all of both sexes were "ripe." Both sexes were stripped and the eggs fertilized. The eggs were smaller than usual but began normal development in hatchery troughs. Several albinos were included in group B and albino males were ripe on August 31. Lack of pigmentation did not prevent their response to the experimental lighting.

This experiment shows that these fish respond to reduction of daylength after long days and they may therefore be said to be negatively sexually photoperiodic, as already noted to be the case in deer and sheep.

These are the first published experiments showing sexual photoperiodicity in fish. Previously temperature was believed to be the controlling factor in fish, at least in the later stages of sexual activation (33).

CONCLUSION

Further experimentation along the lines described should bring out many other facts regarding the possibility and practicability of modification and control of breeding cycles in animals, domesticated, semi-domesticated, or wild, by changes in their environmental conditions. It is evident that control of length of day and of type of food are potent methods of controlling the times at which animals may breed and of increasing or prolonging their productivity.

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SOME CENSUS METHODS FOR MAMMALS

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Accurate information about animal populations is desirable in almost every ecological investigation. It is often important to know the population density of a species at a certain place, the total of its individuals living in a given area, or the fluctuations in its numbers from year to year. Information of this kind is especially needed by the wild-life manager and the conservationist. In practically every study of natural history the taking of one or more censuses would be desirable, if only they could be taken accurately and without too great effort.

Unfortunately, it is very difficult to obtain an accurate census of any kind of mammal even on a small area. Many species are shy and avoid the presence of man. In addition, many forms are nocturnal, and nearly all the smaller species make use of burrows in the ground or of holes in trees, in which they spend most or all the daylight hours.

In spite of these difficulties technics are being developed for making counts of the numbers of certain species on restricted areas. Jack rabbits, deer, and some other kinds of large mammals can be counted more or less accurately by means of drives. Counts of some of the smaller mammals can be secured by intensive trapping. Indications of abundance are given by counts of tracks and of other signs. Although we have yet much to learn about how to secure a satisfactory enumeration of any species even for a small area, good progress is being made in developing useful census methods.

The taking of a complete census of any mammalian species over a large area is usually impracticable and calculations of the size of populations must in nearly all cases be based on counts or estimates of the animals present on relatively small sample plots. In selecting these sample plots all the precautions necessary in taking samples for any statistical purpose must be observed. It is especially important to avoid any bias, conscious or unconscious, in choosing the areas. Either an especially good habitat or an especially bad one might contain quite a different concentration of the species under consideration than the average of the whole area.

No single statistical sample, unless it be very large, can give more than a rough approximation of the size of the population from which it was taken. If possible, therefore, several sample plots should always be counted and the mean of these samples used as the basis of calculation. With figures for a number of samples at hand there are simple statistical methods available for determining the probable accuracy of their means. It is obvious that the greater the number of samples and also the greater the size of the individual samples the more accurate the calculation of the population will be.

The greatest difficulty in making an accurate count of the animals on any area is to prevent the animals which are

on the area leaving before they are counted, and to prevent other individuals from outside the area coming in. It is not at all safe to assume that the outwanderings and inwanderings will balance each other. Timid animals, such as deer, may be disturbed by the placing of the men who are to make a drive, and some of the animals may escape from the area to be driven before the lines are established. On the other hand, if the count is made by trapping over a period of several days, some animals from outside the area trapped may in the course of their wanderings come inside the area and be caught (Chitty, 1937: 42–52). Furthermore, if the individuals living on an area be removed, other individuals may move in to take their place. Some of the unreasonably high counts per acre reported for small mammals are probably due to this cause.

One way of preventing the movements of animals on or off a census area is to select an isolated tract which is surrounded by habitats unsuitable for the species being counted (Hamilton, 1937: 780–781). The isolated area can either be a woodlot surrounded by fields, if a forest inhabiting form is being studied, or a meadow surrounded by woods, if the form to be studied is limited to meadows. It is not certain however, that an isolated area will usually have the same density of population as a larger area of the same habitat type. The boundaries of the individual home ranges of the mammals at the edges of an isolated area would necessarily be somewhat more restricted than on a larger area. Further, the habitat conditions are not the same at the edge, as in the interior of a woodlot or meadow. Some species are probably more abundant at the edge of the forest than they are in its interior, other species are most abundant away from the forest border. These sources of error might lead to erroneous conclusions if the population density in a small area is used as a basis for calculating the population of a larger area. Nevertheless, the determination of the populations of small isolated areas should give much information about total populations. Some species of small mammals occur mostly in restricted local habitats and these species must properly be studied in such situations.

Theoretically, it should be possible to build a fence around a small selected area within a large uniform habitat and then to count the animals inside. The labor involved would be considerable, however, and great care would have to be taken that the disturbance of building the fence would not drive some of the more timid forms off the area. Furthermore, the fence would interfere with the normal movements of the animals onto and off the area and this unnatural barrier would, therefore, prevent the securing of information about normal populations.

The disturbance caused by the investigator walking over, and setting traps on an area may drive off some of the animals. Intensive trapping in a small area may even damage the vegetation, nest sites, and runways so greatly as seriously to alter the suitability of the habitat for small mammals.

Not all the individual mammals which occur on any given area at a particular time are necessarily resident there. At certain seasons of the year a

considerable proportion of the members of the species may be wanderers with no fixed home. Due attention must be given in any computation of animal populations to the possible presence of such unattached individuals. Young animals of the year are especially likely to be wanderers, and the trapping records, therefore, should distinguish the numbers of young and of adults taken. Some young rodents mate and become established at fixed home sites before they acquire the adult pelage, and these sexually mature individuals must be distinguished from the juvenile non-breeding animals.

The males of some species wander more widely than the females, and the numbers of each sex, therefore, must be recorded separately. Though young animals and males may be more inclined to wander than adult females it must never be assumed without positive information that all adult females have fixed home ranges nor that all young animals and all males are wanderers.

One of the most accurate methods for taking a census of the small mammals on a given plot is to trap and mark each animal on the area, liberating it where it was captured. Care must be taken not to attract an unusually large number of individuals to the area by the food provided as bait. If the trapping is efficiently carried out and is continued for a sufficiently long time it should be possible to determine the home range of each individual living on the area. Then by plotting these individual ranges on a map, the resident population of each species on any part or on all of the area can be computed and the number of wandering individuals present at any given time can be counted with considerable accuracy. This method is being used by W. H. Burt with great success in studies of the woodmouse on the George Reserve of the University of Michigan.

The greatest objection to this method of determining populations is the laborious trapping required. Further the method is not applicable to those animals which are trap shy and which therefore cannot be enticed a second time into a trap.

The population of a diurnal species of mammal on a specified area could be determined by a rapid count of all the individuals present, if these had previously been trapped, given distinctive marks that could be read at a distance, and released. Some individual mammals can be recognized by reason of deformities, or other individual peculiarities such as a bobbed tail, crippled leg, or white spot. However, these natural marks are seldom sufficient to distinguish all the individuals of a species living in a given area. We have made some attempts to apply recognition marks to trapped mammals of a few species by clipping off the hair of certain parts of the tail or of the upper parts of the body, and also by applying spots of dye to the pelage. So far these attempts have not been very successful, both because the marks are hard to read at a distance, even with field glasses, and because both the dyed and the clipped areas soon disappear. Further experiments with individual recognition marks on deer, squirrels, chipmunks, and other diurnal animals are desirable.

Some attempts have been made to mark individual animals so that they

may be identified by their tracks. A coyote sometimes has a deformed foot which leaves a distinguishing mark. Adolph Stebler, of the Michigan Game Division, has removed toes from the feet of coyotes, hoping that the marked animals could be recognized by their tracks. R. L. Trippensee, while at the University of Michigan, tried the application of soluble stains to the feet of cottontail rabbits. However, these technics are still in the experimental stage.

In the summers of 1935 and 1937, during field work sponsored by the Carnegie Institution of Washington, I made an attempt to work out methods of counting the numbers of small mammals on measured plots. Some of these studies were made in the sand hills of Nebraska, some in the Black Hills of South Dakota, and a few in the mountains of southern New Mexico. Metal box traps taking the mammals alive were used exclusively, and all the individuals captured were removed from the area. Most of the traps were of mouse size, but a few were of chipmunk size.

The traps were set at first in a checkerboard pattern, with traps 1 rod apart in each direction, and in plots made up of multiples of a square chain. A checkerboard setting is undoubtedly best for long-continued studies which aim to determine the home ranges of all the individual animals on a plot. It was soon discovered that to set and to examine traps distributed in a checkerboard pattern, however, requires a very large amount of walking, with numerous trips back and forth across the plots. Furthermore, if the traps must be set at particular points they will not always be placed in the most suitable spots for capturing small mammals. The setting of traps in the checkerboard pattern was, therefore, abandoned as inefficient in securing a rapid count of the mammals present on a plot.

A simpler method of setting traps for small mammals over measured areas is to mark out plots measuring 4 or more chains on a side (putting wire stakes with small flags of red cloth at the corners of each square chain) and setting the traps in line, 4 or 5 traps to the chain, completely across the plot. The return trap line is similarly set along the next surveyed transect, which is just 1 chain length away. The area is, therefore, covered by traps set 1 rod or less apart in lines 1 chain apart.

The plots used in these studies were laid out in fractions of acres rather than in metric divisions because in the United States large areas are always measured in acres and square miles. A surveyor's chain is 66 feet long, and a square chain is one-tenth of an acre, so the sizes of the plots are easily calculated.

The quadrats covered by these traps were usually entirely trapped out in 3 to 5 nights. On some plots in yellow pine habitat I set new lines of traps in the opposite direction across the quadrat after the other traps had been set for 5 days, but failed to secure any additional mammals, except at the edges of the quadrat. In certain other types of habitat a longer or a shorter trapping period might be required completely to denude an area of its small mammal population.

With any method of trapping on an area which is divided into equal parts

it is possible and desirable to keep the records according to the subunits. It will then be possible to compare the catch in the outside trap lines around the area with the catch in the inner lines, and perhaps determine the amount of inwandering during the period of trapping. It should also be possible to learn by comparison of the numbers trapped in the different subunits whether there are variations in abundance correlated, perhaps, with differences in habitat types.

In thick brush or timber and on very steep slopes it is impracticable to run traps in straight lines. In such situations the traps can be set in irregular lines following trails or any other feasible routes across the area. If the lines are close enough together to cover all the home ranges of the resident small mammals, the entire population should be removed from the area within a few days. Measurements with a steel tape and compass along the boundary lines will afford sufficiently accurate data for the computation of the area covered by the traps. This method of setting the traps avoids the labor of surveying the exact location of the trap lines. It may be employed in any situation where it is desired to know the area in the plot which is trapped, but where the exact spacing of the trap lines is not considered important.

The area which will be denuded of small mammals by any setting of traps extends of course beyond the area actually covered by the traps, unless this area is surrounded by unfavorable habitats. If the individuals of the species concerned are not established in definite home ranges, but are moving about at random, it will be impossible to calculate exactly the area trapped out by a trap line or trap quadrat. But if the mammals are living in fixed homes and have definite home ranges, which they travel over at frequent intervals, it should be possible to estimate the average distance from which the animals come to the traps. There is good evidence that many species of small mammals do have more or less definite home ranges at least during certain parts of the year.

The average shape of an individual cruising range should theoretically approach a circle in form. If adjacent territories are defended by their occupants, the home ranges should tend toward a hexagonal shape. However, it is difficult to calculate the number of circular or hexagonal individual ranges included in any given quadrat. For statistical purposes, therefore, the individual ranges may be treated as though they were square. The mean width of an individual range will accordingly be considered to be the square root of the average area ranged over by an individual of the sex and species under consideration.

An efficient line of traps should capture eventually all the individual mammals having home ranges which overlap the line at any place where there is a trap. If the traps are placed closely enough together in the line so as to be practically continuous the influence of the trapline should extend on each side to an average distance of half the mean width of an individual cruising range for the sex and species concerned. Different species undoubtedly vary considerably in the mean widths of their cruising ranges and the distance on each side of a trap line or plot trapped out

varies, therefore, with the species concerned.

It is obvious then that in order to calculate the area trapped out by a given setting of traps it is necessary to know the average area covered by the cruising range of a single individual of the species concerned. This information can best be secured by intensive live-trapping and marking as already described. If the mean width of a home territory for the sex and age class considered is already known, then the total area trapped out by a given setting of traps is the area covered by the traps plus $\frac{1}{2}$ the mean width of a home territory on each side of the trap quadrat.

Because the cruising ranges of the males may be larger than those of the females it follows that the area denuded of males by any given setting of traps may be larger than the area denuded of females. The calculation of the size of the male population per unit area must, therefore, be made independently of that of the female population.

Furthermore, if the trapping is carried out at a season when some of the animals do not have fixed home ranges, it will be necessary to determine from how great distances these wanderers have come to the traps. In some cases it will be impossible to make such a determination. If the traps are only left set for a few days, however, it may be permissible to assume an arbitrary distance beyond the trap lines from which these invaders have come. Possibly the arbitrary assumption of the same area as is calculated to have been denuded of adult males will sometimes be sufficient for a rough calculation of the population of wandering animals.

A calculation that should give a rough indication of the average size of the individual home ranges on any given quadrat is here suggested. This method assumes that all the individuals of the species, sex, and age concerned are living in more or less fixed home ranges which adjoin but do not overlap each other. The formula to be used is: $Nx^2=(A+x)(B+x)$, in which, N is the number of adults of the sex or age group being considered known to be living on the quadrat; x the mean width of an individual home range; A the width of the quadrat from outside trap to outside trap; and B the length of the quadrat. If a complete record is secured of all the individuals living on the area, the value of N is the number of individuals of that sex and age class trapped. If the plot is not rectangular in form a slight modification of the formula will be necessary, the requirement being that to the area covered by the traps is added a surrounding strip $\frac{1}{2}x$ wide.

As an illustration of the use of this formula let us assume a hypothetical quadrat on which traps have been set over a rectangular plot 100 by 200 yards in outside dimensions, and, further, let us assume that on this plot there have been trapped a total of 10 adult females. Then, interpolating in the formula we have:

$$10x^2=(100+x)\ (200+x)$$
$$10x^2=20{,}000+300x+x^2$$
$$0=20{,}000+300x-9x^2.$$

This is obviously a quadratic equation, which when solved algebraically, gives 66.6 yards for the value of x. Therefore 66.6 yards is the mean width of the home range of an adult female for the data and assumptions given. The area

from which adult females were secured by the traps extends on the average one-half of 66.6, which is 33.3 yards, on each side of the plot beyond the setting of traps. The average area of the home range of an adult female is x^2, which is 4,444 square yards.

The average size of the home range of an adult male can be calculated by the same formula. The method cannot be used for the calculation of the number of individuals per unit area if these individuals do not have fixed home ranges.

One of the most important sources of error in calculating the size of individual home ranges by this method lies in the probability that the individual ranges of the species and sex concerned may not completely fill the area where the trapping is done. The resulting error would give too large a figure for the mean width of a home range and would, therefore, indicate that the area denuded by the trapping was larger than actually the case. This in turn would give too small a figure for the total population per unit area calculated from this data.

Other possibilities of error are that some of the adults may not have fixed home ranges; that the ranges of certain of the adults of the same sex overlap; that some individuals escape capture; and that some of the immature animals also have fixed ranges. An inspection of the data may determine which of these sources of error is likely to be present and a correction of the estimated size of the average home range may then be possible.

For the calculation of the numbers of wandering animals per unit area the most accurate basic data will be secured from intensive trapping conducted on a quadrat for only one, or at most a few nights. If all the individuals present on the trapping area could be secured in one night this would give the most accurate record of the number usually present on the area at one time. If the trapping is continued on later nights, wandering individuals may come in and thereby increase the apparent concentration on the area. It is not known, however, how much error is produced by including in the calculations all the individuals taken over a trapping period of say 3 days, which is the usual duration of trapping on an area.

Traps set for only one night cannot be expected to catch all the animals with fixed home ranges impinging on the trap line, for some of these animals may not visit every part of their ranges every night. Ordinarily, trapping must be continued until no more adults are being taken. It should theoretically be possible by setting the traps very closely together to secure all the small mammals on an area in one night, but this would require an impracticably large number of traps. The intensive trapping desirable for securing an accurate count of the number of wandering animals present on a quadrat is, therefore, not the type of trapping best suited for determining the number of individuals having fixed ranges on the area.

The outside lines of traps on a quadrat should catch a greater number of wandering animals than the traps toward the middle of the quadrat. By comparing the numbers taken in the two situations it should theoretically be possible to estimate the proportion of wanderers taken. The difference in the

numbers taken in the inner and outer traps should be greatest when the traps are kept set for a long period of time. Little useful information will be given by such a comparison, however, unless the size of the quadrat is many times greater than that of an individual home range.

A buffer line or zone of traps partly or completely surrounding the quadrat being studied has been used by some investigators (Elton, Davis and Findlay, 1935: 283–284) to prevent the inwandering of non-resident animals. Such a line of traps cannot ever be completely successful, however, in preventing wandering individuals from reaching the area, for some will certainly pass between the traps in the buffer zone. Furthermore, some of the individuals living on the quadrat will likely be caught in the outside line of traps, and it will be impossible to distinguish these from animals coming in from outside. It takes a large number of traps to surround a quadrat and it seems wasteful of time and energy not to make use of the information secured from these traps. A surrounding line of traps in my opinion does no more than increase the size of the quadrat, and it is still necessary to determine the distance beyond the traps from which the animals have come.

The larger the area covered by trapping operations of uniform intensity, the more accurate can be the determination of the populations of the included mammalian species. All the calculations are based upon averages and no statistical average can be very reliable when based only on a few data. Computations from any number of individuals less than 10 cannot give a very reliable average for the size of a home range.

On large quadrats, also, there is proportionally less opportunity for movements of the inhabitants on or off the plot. This is true because the area of a square plot varies as the square of the length of the side, while the length of the boundary of the plot varies directly with the length of the side. Furthermore, on large plots any error in calculating the width of the surrounding strip from which animals are trapped is minimized. In the case of small quadrats the area included in the surrounding strip may form a considerable proportion of the whole area from which animals are taken. With large plots, on the contrary, the surrounding strip forms only a small part of the total area from which the mammals are collected, and errors introduced in the calculations by failure to estimate correctly the width of the surrounding strip are relatively unimportant. The size of quadrat required in order that these errors will be negligible depends of course upon the size of the average home range and will have to be calculated separately for each species.

It is not necessary to kill or remove the animals taken on a quadrat in order to secure an accurate count. If taken in live traps the animals can be released without harm. If the trapping is to be continued longer than one night the animals should be marked before releasing, so that they can be recognized when subsequently trapped. A small notch cut in the ear, or a tuft of hair clipped from some part of the body will be sufficient unless it is desired to make a long-continued study of individual home ranges.

An expanding quadrat can be used to cover a large area with a limited number of traps. The traps are first set in the middle of the area. As soon as these traps have denuded their vicinity they are removed and reset in lines surrounding the first settings. The amount of expansion possible will of course be limited by the number of traps available and the distance they are set apart.

A moving quadrat (Townsend, 1935: 16) differs from an expanding quadrat in that the expansion is on only one side. Wandering animals can be expected to come into a moving quadrat not only from the front and from both sides, but some may catch up with it from behind.

While traps set in large quadrats will undoubtedly give the most accurate information about the populations of small mammals, there are many occasions when it is impracticable to set traps in this manner. At such times traps set in straight or nearly straight lines of measured length will give much information about relative populations and under favorable circumstances it may be possible to estimate actual concentrations per unit areas from the data so obtained.

A line of thoroughly efficient traps should denude an area extending for one-half the mean width of a cruising range on each side of the traps, and also for one-half the mean width of a cruising range beyond each end of the line. This is on the assumption that all the individuals of the species being trapped are living in relatively fixed home ranges. If the mean width of a cruising range for the sex and species concerned is known from previous studies it will be possible to calculate the area trapped out by the trap line and from this to determine the population of the species per unit area.

If the average size of a home range for the species concerned is unknown it is still possible to make an estimate of the mean width of a home range by a simple computation. Divide the length of the line of traps by 1 less than the number of adults of the species and sex concerned, captured during the period of trapping. The quotient should be the mean width of a home range. It is assumed in making this computation that all the individuals of the sex and species considered have fixed ranges which adjoin but do not overlap, and that all whose ranges overlap the trap line are captured. The computation will not give a very accurate figure for the mean width of an individual range unless the line is long enough to cover a considerable number of ranges.

If the trap line extends completely across a habitat which is surrounded by other types of habitat unfavorable to the species being studied, the calculation should be corrected as follows: To find the mean width of a cruising range divide the length of the trap line by the exact number of individuals of the species and sex captured. In any other situation the traps on the end of the line will capture individuals whose ranges extend beyond the trap line. As usually set, the trap line should capture a number of individuals 1 greater than the number of individual ranges included in the length of the line.

If several trap lines have been run in the same season through uniform habitat in a given district, it is statistically proper to combine the several means of

cruising range width obtained and thus get a more exact combined mean. The precaution must be observed not to use figures from trap lines set so closely together that some individual ranges might be touched by two lines.

The length of the trap line should be measured with a steel tape if possible. Counts of paces should be resorted to only as an emergency measure.

Moderate curves in the trap line should not cause any important error in the computations, but very sharp curves in the line should be avoided. The sharpest curve allowable would have a radius equal to half the mean width of the largest home range of any of the species considered.

The single trap line of measured length cannot be expected to give as reliable data on mammal populations as the trap quadrat. Only rarely will it be possible to calculate accurately the average size of the home range of any species and of the population per unit area from information secured entirely from single trap lines. Nevertheless, if trap lines are run in a standardized manner in different places or at different times they should give a reliable indication of the comparative abundance of species taken on all of them.

It might be supposed that counts of the tracks of any selected species of mammal crossing a given length of trail could be used according to the above suggested method to calculate the average size of the home range and the population of the species. Before the method can be used in that way, however, there will need to be demonstrated that the individuals of the species concerned have mutually exclusive ranges. Further, it would have to be made certain that no individual is counted twice. It will be difficult to determine from tracks alone whether one or several individuals have made tracks which cross the trail. Only rarely will there be distinctive features or sizes which positively identify the maker of a certain track. The number of tracks of any species crossing a unit length of trail does give an index of relative abundance, and it is possible that this index of abundance may later be correlated with actual population densities determined by other methods.

The number of animals caught per "trap-night" has occasionally been used as an index of abundance, following an early suggestion by Grinnell. From the preceding discussion it will be evident, however, that the number of animals secured on a trap line depends largely on the sizes of the individual cruising ranges of the several species present in the region. If all the individuals with cruising ranges crossing the trap line are ultimately caught the number taken is not directly related to the number of traps nor to the length of time they are set, but is directly related to the length of the trap line. I believe, therefore, that the statement of the numbers of individuals of each sex and age taken per unit length of line is a better method of stating abundance than is the catch per trap-night.

To supplement actual census methods, which often are expensive or impracticable, simple methods of obtaining indices of abundance are greatly to be desired. Attempts have been made to use for this purpose counts of tracks, of homes, and of other evidences of the presence of certain species. MacLulich (1937: 25–39), in a study of the cycles

of abundance of the snowshoe hare, has employed an interesting statistical method to show that counts of droppings on a series of small quadrats give a reliable index of the relative abundance of the animals.

It is not always necessary that indices of abundance be directly convertible into census figures, for the knowledge that certain species are increasing or decreasing or that they are most abundant in certain types of habitat will often be of great value to wild-life administrators. As yet no standardized methods have come into general use for securing indices of the abundance for mammalian species. This is, however, a most promising field for experiment.

The use of the frequency index for comparing the abundance of mammals at different times and places was suggested several years ago (Dice, 1931: 378). It is true that the frequency index shows primarily the uniformity of distribution of a species rather than its comparative numbers (Cain, 1932: 478). However, it has been shown by McGinnies (1934: 281) for plants that there is a correlation between the frequency index and abundance. Any one kind of mammal probably has everywhere the same general type of local distribution, and therefore its frequency index for different locations or for different years should give a good indication of its comparative abundance. Where signs of occurrence rather than actual counts of individuals must be depended upon for comparing the abundance of animals, the frequency index is of special value. This is shown in its use (under the name of "trace census") by Elton, Davis, and Findlay (1935: 280–281) in a study of fluctuations of the numbers of voles.

No one census method can be used for all kinds of mammals. The several species differ so much in size and in habits that many different methods will have to be devised, perhaps a distinct method for each species. It is obvious that a very different technic must be used for counting the numbers of mice and of grizzly bears. However, some methods may, with slight modification, serve for the enumeration of several different species.

In any study of population the determination of the size of the individual home range is of great importance. Except for the rare instances in which the whole population of a circumscribed area can be counted, estimates of populations will usually involve a determination of the average size of the individual range. Studies of home ranges, to be most useful, should include a detailed determination for each species of the mean and extreme areas included in the cruising ranges of males and of females, and also of old and of young individuals. Due consideration must be given to possible variation in the sizes of the cruising ranges at the various seasons and in the various types of habitats occupied. The studies should determine also whether the individual ranges are mutually exclusive, or if several individuals may under certain conditions occupy parts of the same range at the same time. Of importance in this connection is the determination of the location of the nest in relation to the home range and of the relationship between the abundance of suitable nest sites and the spacing of the individual ranges. It is to be hoped that in the

future field naturalists will give increasing attention to detailed studies of the individual ranges and of the populations of all kinds of mammals.

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THE CARRYING CAPACITY OF BIG GAME RANGE[1]

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The carrying capacity of any given big game range in regions of highly diversified topography is quite uncertain. Especially is this true of mountain winter ranges which are often covered with two or more feet of snow for several months and support coniferous trees and deciduous browse as the principal available forage for elk and deer. It is the object of this paper to set forth briefly a plan whereby the carrying capacities of such ranges can be determined.

Until recently the limiting factor in big game range surveys has been the lack of methods that would give reliable quantitative data. This condition has been partially corrected during the past four years by the introduction of the square foot density method for the determination of plant cover and the use of the airplane in scouting animal populations. With these two new tools, and the best of the old methods available for wildlife workers interested in the carrying capacities of ranges, it is obvious that we may go forward with assurance that more trustworthy results can be obtained.

Before attempting to explain how these new methods can be successfully employed in the field, it would seem desirable to review what one might expect to find on a typical big game winter range in Idaho during a critical winter period. I shall draw freely at this point from information reported from the big game (especially elk) grazing studies made from 1935 to 1937 on portions of the Selway Division of the Bitterroot National Forest and on the Nez Perce and Clearwater National Forests of northern Idaho.[2] These ranges, where the studies were made (not the regions as a whole) carry approximately 9,000 elk, 4,200 mule deer, and 2,600 white-tailed deer. The winter grazing season in these regions is divided into two periods: the first or early winter includes November and December, while the late winter period extends through January, February, and a part of March, or until a general thaw occurs. The latter season may comprise as a whole, or in part, the critical period when snow is deep and the elk migrate to the lower elevations of the south slopes. Here they seek forage, shelter, and warm exposures. The elk's food in this particular environment is composed of 90 per cent browse, 4 per cent grasses, and 6 per cent weeds. During certain periods when there is moderately deep crusted snow the food, of the elk may be practically 100 per cent browse, including coniferous trees. Since an elk on such an area may eat all of the twigs of a bush including those up to about an inch in diameter, devastation may result on overstocked range. Overbrowsing is aggravated because the elk return to the same range

[1] Paper presented at the Idaho Game Management Conference, Moscow, Idaho, December 8–10, 1937.

[2] Permission was obtained from the Wildlife Division of the Forest Service, Region 1, to use certain unpublished data.

year after year and eat the same kind of browse. On these particular forest ranges the most palatable browse plants are species of Ceanothus and Salix. These are often quite sparsely represented, especially so on some of the footslopes most desirable for elk range. According to data (Table 1) obtained in the studies made on the Nez Perce and Clearwater National Forests *Ceanothus velutinus*, *C. sanguineus*, and Salix[3] have an average palatability of 75 per cent, while the other available browse species are only 5 per cent or less palatable to elk. It is obvious therefore that the carrying capacity of an elk range during a critical period of the winter depends upon the most palatable forage available, which may be limited to a few species.

TABLE 1

AVAILABLE AND PALATABLE BROWSE PLANTS OF ELK WINTER RANGES ON THE NEZ PERCE AND CLEARWATER FORESTS OF IDAHO

		Per Cent Available	Per Cent Palatable
Redstem	Ceanothus sanguineus	25	80
Snowbrush	Ceanothus velutinus	5	70
Willow	Salix sp.	20	60
Oceanspray	Sericotheca discolor	10	5
Ninebark	Opulaster malvaceus	10	5
Snowberry	Symphoricarpos sp.	10	5
Mockorange	Philadelphus lewisii	5	5
Chokecherry	Prunus sp.	5	5
Others—Mostly Oregon grape, elderberry, serviceberry, and mountain maple		10	5

The use of the square foot density method is highly desirable for the determination of the carrying capacity of big game ranges under normal conditions and with certain modifications would be applicable to specific areas during critical winter periods. The square foot density method as used in range surveys is a means of sampling vegetation by randomized replicated plots. Each plot is a circle 100 square feet in area with a radius of 5.64 feet (or 5 feet 7.8 inches). The density of each species within the plot is determined by the use of a wire frame one foot square divided into quarters. A square foot of ground completely covered with vegetation but with no overlapping of parts when viewed from above is the standard for estimation of density. Therefore, if the entire plot is equally covered with vegetation it is said to have a 10/10 density. The number of square feet of 10/10 density recorded for a given species represents the percentage of the total ground area covered by that species, because a square foot is one per cent of the total area. The area times the volume density times the palatability gives a forage acre valuation. The standard forage acre may be defined as an acre area having a 10/10 density cover of palatable vegetation; the valuation figure indicates the relative carrying capacity of a unit of vegetation. With consider-

[3] Species not determined because all forms seemed equally palatable.

Western mountain maple overbrowsed by elk. (Courtesy U. S. Forest Service.)

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able practice the range examiner may be able accurately to estimate visually the density of a given species in the plot. Both top and lower story determinations of the vegetation can be made if desired.

On these critical winter ranges for elk a sufficient number of square foot density plots may be distributed over selected areas to obtain an appraisal of the available forage. Since the available and palatable browse or forage may be composed of bare twigs to an approximate diameter of one-fourth of an inch they must be compactly grouped on each bush by means of a wire or heavy cord in order to insert them into the square foot wire frame for density percentage determinations. This method would at first call for the services of two men, but with considerable practice one man may be able to handle the operation alone.

The fact that elk graze shrubs higher than either deer or cattle must be considered and means should be provided by the range examiner to meet this condition.

The square foot density method can be used also for clipping determinations. In each plot a square foot of browse twigs or any portion of the plot desired may be clipped off to the grazing diameter for each species under consideration and wet and dry weights determined. These data will give both the volume density and weight density for the species in the area. The carrying capacity can then be determined on the basis of the dry or wet weights in relation to palatability. Such determinations should be made each year and the effects of severe overgrazing on the growth of the browse species for one or several seasons obtained. Several check plots should be selected in the areas and provision made for their complete protection in order that accurate comparisons of browsed and unbrowsed areas can be made from year to year. The effect of various degrees of grazing intensity not only should be studied under normal climatic conditions, but also in drought years. Overgrazing associated with severe drought seasons appears to be a major problem on some of the wildlife ranges. A careful study should be made also of the physiological effects on the shrubs of the removal of a large proportion of the twigs each season (Plate 6). The effect upon the crown growth when the terminal buds of the twigs are removed may be vital in relation to the survival of certain species.

The forage density and poundage data lose their significance in solving big game range survey problems unless animal population determinations for correlation purposes can be made with a good degree of accuracy. The following methods are suggested to obtain population counts of elk during a critical winter period on the mountain ranges.

First, by the use of airplane observations covering large areas, to locate small herds when the animals are forced to leave the higher timber-protected areas in order to graze in the more open browsing range. Second, by placing men with binoculars in the field in desirable locations where elk are more or less concentrated, to count the animals present. In certain localities camps may be established which overlook a

localized range and from which careful counts may be made during all periods of daylight.

It would also be very desirable to establish enclosures where a few elk can be intensively studied in relation to their feeding habits. By such a procedure more definite palatability data can be obtained, as well as quantitative data from which could be calculated the actual amount of forage an elk may consume in different environments. Such data would be very valuable for comparative purposes in future big game range surveys.

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THE FEEDING HABITS OF THE MONTANA GRAYLING (*THYMALLUS MONTANUS*)[1]

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An investigation basic to a management program for the grayling in Montana was begun in the autumn of 1935 and extended intermittently through the next two years. Certain aspects of this study were carried out with the aid of a grant from the National Research Council. Due to a change in residence, it was not possible to complete the proposed program, but some of the data seem to have sufficient merit for publication. The food habits study is the first to be presented. Acknowledgments are due Elmer G. Phillips, former superintendent of fisheries in Montana, and the late Harry L. Johnston, superintendent of the Bozeman Station, for their fine cooperation in this study. I am indebted to Professor M. H. Spaulding, who shared in the collection of material, and to the U. S. Bureau of Fisheries for furnishing most of the equipment and the hatchery facilities.

Artificial Feeding

The difficulties involved in the artificial propagation of grayling have in practically all instances been those of feeding. Certain fish culturists have contended that grayling fry differed from the other coldwater game fish in that they required living food, such as the plankton of streams or lakes. According to this notion, the ordinary meats and meals used in the culture of trout were entirely unsatisfactory. Laird (1928) and Lord (1932), as well as several other fish culturists, have demonstrated that the problem is concerned more with the size of the food particles and the frequency of feeding than with the kind of food itself. Certain recommendations call for the use of beef liver or heart to be ground as many as 10–20 times through a plate with 1/64-inch openings. The feeding process consists of forcing the finely ground meat through a fine mesh screen into the water of the holding troughs. The interval of feeding recommended varies from 1–3 hours throughout the working day. By this method it has been possible to carry grayling past the difficult fry stage with no more than the expected loss. The fingerling and adult grayling are as easily cultured as trout by using the more or less standard hatchery methods and diets.

Experimental Feeding with Natural and Artificial Food

Henshall (1899, 1907) was able to rear grayling past the fry stage only when he supplied them with creek water containing natural food. He described this as consisting of *Daphnia*, *Cyclops*, shrimps, and snails. It is hardly probable that these organisms actually were the important foods since the water used (Bridger Creek) contains little or no plankton Entomostraca and since it would be utterly impossible for the fry to feed upon any

[1] Contribution from the Institute for Fisheries Research, Michigan Department of Conservation and University of Michigan.

of the ordinary shrimps or snails because of their size. Elmer G. Phillips had less than a five per cent mortality during the first 2½ months in grayling fed on a diet of total net plankton from Albert Lake, near Libby, Montana. An examination of the plankton from this lake showed it to consist almost exclusively of *Daphnia* and *Diaptomus*.

An experiment was undertaken to determine whether or not grayling fry would exercise selection when offered the total plankton of lakes. About 5,000 fry held at the Meadow Creek station (water temperature 45–48°F.) were presented total net plankton from Meadow Lake at three hour intervals, starting the third day after the peak of hatching. Each day following, at 20–30 minutes after the first feeding, the stomach contents of 25 fish were subjected to microscopical examination. The first finding of food in the stomachs was in nine day old individuals and only a small number were found taking food before the thirteenth day. These results are surprising, considering the early attempts at feeding made by most of the fry. After the fifth day there was marked activity each time plankton was introduced. Time after time the tiny fish would try to take adult Entomostraca but without success, as shown by subsequent examination of their digestive tracts. Apparently the small size of the mouth at this stage prevents the taking of food organisms. Trout fry, on the contrary, were able to eat even the largest plankters on their first day of feeding. Between the time food was first taken and the fourth to fifth weeks, the food eaten was confined to the nauplii of Cladocera and Copepoda with an occasional filament of algae. After the fifth week practically all of the fry stomachs examined contained both nauplii and adults of Entomostraca as well as small numbers of rotifers, protozoans, and algae. The absence of algae was so conspicuous in view of their relative abundance that it is safe to conclude a degree of preference was shown for the Entomostraca. In all of the fish (1–5 weeks old) examined, which amounted to several hundred, the maximum number of organisms taken by a single fish during the 30 minute interval following the introduction of food, was 22, and the average eight.

In a later experiment conducted at the Bozeman station (water temperature 49–52°F.) in which artificial food was used, the first evidence of feeding occurred in five-day old fish. By the seventh day more than 90% of the fry in these troughs had food in their stomachs. It is obvious that both the temperature of the water and the size of the food particles affect the time when fry will begin feeding.

A few grayling fry placed in a pond at the Bozeman station were observed to live almost entirely on midge larvae. Of 12 fish examined, all had these larvae in their stomachs. The only other food items taken consisted of a few blue-green algae, one *Cyclops*, and 11 immature Copepoda. Forty-seven tiny midge larvae were found in one 20 mm. fish.

There is some evidence that grayling fry are mainly day feeders. Those placed in dark troughs remained comparatively inactive even when concentrated plankton was introduced. Electric lighting immediately above the troughs greatly increased feeding activity.

NATURAL FEEDING

The fact that grayling are so easily caught at times indicates their voracity. Parker (1888) observed the Michigan species during its natural feeding activity and records 50 rises in 15 minutes for one fish. They feed both deep and at the surface and seem to take food species except fish as they are available. In all of the specimens collected for study, not a single one was without food in its stomach. Grayling are almost invariably found in schools and it is not at all unusual to see three or four individuals rise for the same fly. In one instance, a specimen was taken a second time on an artificial fly within three hours after being jaw-tagged. In coming to the surface for food these fish often swim with enough force to emerge almost completely from the water. Montana grayling fry exhibit many of the qualities of the adult. They feed vigorously and almost without caution.

STOMACH EXAMINATIONS OF WILD FISH

The stomachs of approximately 125 fish were examined. The larger specimens were collected by fly casting, with the exception of about 10 individuals taken from state and federal traps during the spawning season. The fry and fingerlings were captured with small-mesh nets. Collections were made in the artificially stocked waters of Rogers Lake, Flathead County; Agnes Lake, Beaverhead County, Montana; and from Grebe Lake in Yellowstone National Park. A fair number also were secured from the mouth of Meadow Creek, Madison County, Montana, one of the grayling's native habitats. All fish were measured and weighed at the time of capture and their stomachs removed and preserved in seven per cent formalin for later study. Examinations of stomach contents were made in the laboratory with the aid of a dissecting microscope. The organisms found were counted and identified to the larger taxonomic groups, then spread on blotting paper for 1–2 minutes to remove excess moisture and weighed on a torsion balance to the nearest .05 gram. The cc. volume by water displacement was also taken but was found to be practically identical with the weight in grams so is not given in the following tables. The results are tabulated according to localities and sizes of fish; in most cases, the size groups represent age classes. All weight percentages are given in terms of total weight of the stomach contents minus debris. This last-named material, which obviously had no food value, contained such items as sticks, stones, caddis cases and mud.

Very little published information concerning the food of the Montana grayling has come to the writer's attention. A note on stomach examinations of Michigan grayling is given by Milner (1874) in which he lists Coleoptera, Neuroptera, and the larvae of dragonflies as food items. He also found the leaves of the white cedar which he credits to accidental food. Norris (1883) speaking of the Michigan grayling says, "The various orders of flies which lay their eggs in running water, and the larvae of such flies, appear to be their only food." This is especially interesting because in the present study midges (chironomid flies) have been found to be the most commonly occurring items in the stomachs of all sizes of Montana

TABLE 1

SUMMARY OF FOOD ORGANISMS IDENTIFIED FROM THE STOMACHS OF MEADOW CREEK GRAYLING

Kind of Organism		Dates: June 14, 27 and July 10, 1936. Size of fish: 190–250 mm. standard length. Number of fish: 20.						Dates: June 14, 27 and July 10, 12, 1936. Size of fish: 250–335 mm. standard length. Number of fish: 20.					
		Greatest No. in Any Fish	Average No. Per Fish	Per Cent of Fish With Organism	Total Wt. of Organism For All Fish	Greatest* Per Cent of Total Wt. in Any Fish	Per Cent* of Total Wt. of All Food Taken	Greatest No. in Any Fish	Average No. Per Fish	Per Cent of Fish With Organism	Total Wt. of Organism For All Fish	Greatest* Per Cent Of Total Wt. in Any Fish	Per Cent* of Total Wt. of All Food Taken
Aquatic Insects: Mayflies (Ephemeroptera)	Nymph	62	6.2	40	2.4	94	21.9	42	6.0	40	1.7	64	6.1
	Adult	6	0.6	25	0.2	20	1.8	19	1.0	15	0.15	21	0.5
Damselflies (Odonata)	Nymph	8	1.6	40	1.5	81	13.7	20	2.8	45	3.0	44	10.8
	Adult	5	7.5	20	1.0	46	9.1	41	4.1	45	6.2	82	22.4
Stoneflies (Plecoptera)	Nymph	4	2.5	10	0.5	16	4.6						
	Adult												
Caddisflies (Trichoptera)	Larva	1	0.15	15	0.5	22	4.6	2	0.35	20	0.85	70	3.1
	Adult	3	0.2	10	0.15	35	1.4	1	0.05	5	0.1	3	0.4
Bugs (Hemiptera)	Larva												
	Adult	2	0.2	15	0.1	13	0.9	6	1.2	45	0.45	9	1.6
Beetles (Coleoptera)	Larva												
	Adult	1	1.5	15				29	5.[illegible]	65	2.05	52	7.4
Midges (Diptera)	Larva and pupa	56	11.4	95	0.95	92	8.7	46	7.35	85	0.75	9	2.7
	Adult	2	0.15	10				1	0.1	10			
Terrestrial Insects: Grasshoppers (Orthoptera)		2	0.1	5	0.4	29	3.7	8	1.6	50	8.2	70	29.6
Leafhoppers (Homoptera)								6	0.3	5			
Beetles (Coleoptera)		1	0.05	5				1	0.05	5			
Flies (Diptera)		10	1.8	35	0.75	62	6.8	2	0.04	25	0.25	11	0.9
Bees (Hymenoptera)		5	0.35	20	0.20	14	1.8	4	0.04	15	0.35	19	1.3
Other Aquatics: Waterfleas (Cladocera)		937	191	45	2.15	90	19.6	64	4.0	10	0.05	6	0.2
Shrimp (Amphipoda)								2	0.25	15	0.15	9	0.5
Sow Bugs (Isopoda)		4	0.2	10	0.15	66	1.4	19	2.4	25	1.0	29	4.0
Fish (Salmo trutta)								5	0.25	5	2.35	75	8.5

* Debris not included.

grayling. Parker (1888) considered the Michigan grayling as a vegetable feeder and accounts for the flavor of the fish by this assumption.

Meadow Creek foods

The mouth of Meadow Creek constitutes about 150 yards of stream, most of which is directly influenced by the fluctuations of Meadow Lake reservoir. During the periods of high lake level this portion of the stream becomes sluggish but remains considerably colder than the lake. Grayling congregated here during the early summer and were the predominant species, their associates being brown, rainbow, and brook trouts. This is one of the few known ancestral waters still occupied by grayling and the data secured from stomach examinations of the fish should reflect, at least in part, original feeding conditions.

Stomach examinations indicate that large quantities of non-nutritive materials are regularly ingested by the grayling. The item of debris, in the group of smaller fish from Meadow Creek, made up 70.1% of the total weight of stomach contents and in the larger fish constituted 58.8%. The aquatic insects accounted for 66.5% by weight of the food organisms present in the smaller fish and 55% in the larger. Predominant foods were mayflies, 23.7% of the total food in the first group, and damselfly nymphs, 33.2% in the second. The aquatic Coleoptera formed 7.4% of the diet of the larger fish. All of the beetles were adults and more than one-half were *Donacia*, with Dytiscidae, Hydrophilidae, Haliplidae, and Parnidae following in order of abundance.

Terrestrial insects contributed more to diet of the larger fish, 31.8% of the total weight as compared to 12.3% for the smaller. A few large grasshoppers were mainly responsible for this difference, making up 29.6% of the total food for the 250–335 mm. specimens. Other aquatic organisms were chiefly Crustacea, with Cladocera accounting for 19.6% of the total food weight in the first size group and the isopod, *Asellus*, amounting to 4% in the second. Five brown trout fingerlings were found in the stomach of one large female grayling. This was unusual but not surprising, since this fish was caught within 200 feet of the hatchery outlet, where trout fingerlings were concentrated in great abundance. This was the only instance observed where fish of any kind were used as food. According to Svetvidov (1931), the white grayling from Lake Baikal in Russia, feeds chiefly on fish and amphipods. Heckel and Kner (1858) and Siebold (1863) list fish brood and minnows as regular items of food for the European grayling. There are no records, except that here given of fish in the stomachs of the Montana or Michigan species.

Rogers Lake foods

Rogers Lake has proved to be an excellent grayling water. It is free from other species of fish except the cutthroat trout which occurs in very limited numbers. The lake has a maximum depth of about 25 feet and supports an enormous amount of vegetation. The maximum summer temperature is near the upper limit of toleration for trout and grayling (about 80°F.). The fish in this lake were in excellent condition and showed rapid growth.

Sow Bugs (Isopoda)	4	0.2	10	0.15	66	1.4	19	2.4	25	1.0	29	4.0
Fish (Salmo trutta)							5	0.25	5	2.35	75	8.5

* Debris not included.

TABLE 2

SUMMARY OF FOOD ORGANISMS IDENTIFIED FROM THE STOMACHS OF ROGERS LAKE GRAYLING

Kind of Organism		Date: July 19, 1936. Size of fish: 22–50 mm. standard length. Number of specimens: 20.			Date: July 19, 1936. Size of fish: 150–250 mm. standard length. Number of specimens: 10.						Dates: May 24, 1936 and July 19, 1936. Size of fish: 250–338 mm. standard length. Number of specimens: 21.					
		Greatest No. in Any Fish	Average No. Per Fish	Per Cent of Fish With Organism	Greatest No. in Any Fish	Average No. Per Fish	Per Cent of Fish With Organism	Total Wt. of Organism For All Fish	Greatest Per Cent of Total Wt. in Any Fish	Per Cent of Total Wt. of All Food Taken	Greatest No. in Any Fish	Average No. Per Fish	Per Cent of Fish With Organism	Total Wt. of Organism For All Fish	Greatest Per Cent of Total Wt. in Any Fish	Per Cent of Total Wt. of All Food Taken
Aquatic Insects: Damselflies (Odonata)	Nymph	One small dragonfly nymph			10	0.7	10	0.25	69	2.1	3	0.25	15			
	Adult										1	0.50	5			
Caddisflies (Trichoptera)	Larva										4	0.25	10	0.4	10	3.8
	Adult	1	0.05	5	3	0.3	5	0.10	35	0.8	1	0.10	10			
Bugs (Hemiptera)											1	0.10	9	0.15	52	1.4
Midges (Diptera)	Larva and pupa	57	12	90	1,050	446	70	8.45	100	71.3	631	177.0	70		100	
	Adult	33	4.9	60							600	35.0	9	2.0	86	18.8
Other flies (Diptera)	Larva				1,454*	146	10	1.15	98	9.7						
	Adult															
Terrestrial Insects: Thrips (Thysanoptera)		3	0.25	15												
Leafhoppers (Homoptera)		1	0.1	10												
Beetles (Coleoptera)		1	0.05	5							2	0.4	30	0.65	38	6.1
Flies (Diptera)		10	0.25	25	1	0.05	5				1	0.05	5			
Bees (Hymenoptera)		3	0.30	15	1	0.10	10				1	0.30	15			
Other Aquatics: Water fleas (Cladocera)		926	187	85	688	112	30	0.2	25	1.7	3,150	176	20	1.5	67	14.1
Copepods (Copepoda)		47	6	15												
Shrimps (Amphipoda)		4	0.35	15	8	1.7	60	1.7	26	14.3	64	11.2	72	2.95	91	27.7
Snails (Gastropoda)											35	2.4	20	1.35	85	12.7
Water mites (Hydrachnida)		11	2.0	40												
Fish eggs											35	4	14	1.65	100	15.5
Algae												Several small bunches				

* *Corethra*.

Food organisms especially midges were abundant.

There was practically no debris in the stomachs of the 20 fingerlings seined from this lake (see Table 2). The 150–250 mm. specimens contained 25% debris, while the largest specimens had 72.6%. Aquatic organisms made up almost 100% of the total food contents in the 150–250 mm. fish and 74.7% in the 250–338 mm. specimens. Midges and water-fleas were the most important aquatic items of the fingerlings' diet. In the 150–250 mm. specimens, midges made up 71.3% of the total food weight, with amphipods contributing 14.3%. The stomachs of the larger fish contained 27.7% amphipods, 18.8% midges, and 14.1% Cladocera. The fish eggs taken included those of both grayling and cutthroat trout. All of the fish having eggs in their stomachs came from the Montana state fish traps during the spawning season.

The largest variety of terrestrial insects was found in the fingerlings' stomachs, but the only significant item so far as quantity is concerned was the 6.1% of Coleoptera found in the larger size fish. Traces of filamentous algae were rather common. Items not listed in Table 2 were: 10 leech egg cocoons, one terrestrial arachnid, one *Gordius*, and eight nematodes. The last two groups were probably parasites.

Grebe Lake foods

Grebe Lake is situated at an elevation of about 8,000 feet and is one of the more productive mountain lakes, with comparatively shallow water and abundant vegetation. A few rainbow and cutthroat trouts and rainbow-cutthroat hybrids were present along with an abundant population of grayling. The fish examined were in good condition. Food organisms were plentiful, especially the damselflies, *Argia* and *Ischnura*.

Twenty-five grayling fry (19–24 mm. standard length) taken from the east end of Grebe Lake had 53 midge larvae and pupae as well as 21 very small mayfly nymphs in their stomachs. Plankton samples from the same part of the lake showed *Daphnia*, *Diaptomus*, rotifers, and many algae to be present, but none of these had been used as food.

Debris made up 38.3% of the total weight of stomach contents in the larger fish (Table 3). The food organisms consisted of 76.9% aquatic, and about two per cent terrestrial, insects. All of the latter were Coleoptera. About 40% of the aquatic species were midges and 20% damselflies. The aquatic Coleoptera, *Donacia* and Hydrophilidae, constituted 9.3%, amphipods 10.2% and *Asellus* one per cent, of the total food weight. Algae were fairly numerous in many stomachs and accounted for 10.2%. Two 265 mm. fish not listed in Table 3, taken from the traps at Grebe Lake during the spawning season, contained 137 grayling eggs besides one damselfly nymph and two adult Dolichopodidae.

Agnes Lake foods

Agnes Lake is a small mountain lake with barren rocky shoals, situated at an altitude of about 9,000 feet. No fish were present in this lake until about 1930, when grayling were stocked by the Montana State Fish and Game Commission. During the next five years heavy plants were made and there was

Fish eggs			35	4	14	1.65	100	15.5
Algae				Several small bunches				

* *Cordhra.*

TABLE 3

SUMMARY OF FOOD ORGANISMS IDENTIFIED FROM THE STOMACHS OF AGNES AND GREBE LAKES GRAYLING

Kind of Organism		GREBE LAKE Date: July 6, 1936. Size of fish: 125–162 mm. standard length. Number of specimens: 14.						AGNES LAKE Date: June 6, 1936. Size of fish: 250–325 mm. standard length. Number of specimens: 6.					
		Greatest No. in Any Fish	Average No. Per Fish	Per Cent of Fish With Organism	Total Wt. of Organism For All Fish	Greatest Per Cent of Total Wt. in Any Fish	Per Cent of Total Wt. of All Food Taken	Greatest No. in Any Fish	Average No. Per Fish	Per Cent of Fish With Organism	Total Wt. of Organism For All Fish	Greatest Per Cent of Total Wt. in Any Fish	Per Cent of Total Wt. of All Food Taken
Aquatic Insects: Mayflies (Ephemeroptera)	Nymph	2	0.6	40									
	Adult	7	1.1	30	0.2	33	3.7	6	1.0	17.0	0.2	25	10.5
Damselflies (Zygoptera)	Nymph	9	1.0	21	0.8	87	14.8						
	Adult	3	0.4	14	0.3	30	5.6	One adult specimen					
Caddisflies (Trichoptera)	Larva												
	Adult	4	0.6	21	0.2	20	3.7						
Beetles (Coleoptera)	Larva												
	Adult	1	0.4	14	0.5	16	9.3	One Dytiscidae					
Midges (Diptera)	Larva and pupa	137	43	100	2.15	80	39.8	228	56	100	0.75	69	39.4
	Adult	3	0.15	14				One adult specimen					
Terrestrial Insects: Leafhopper (Homoptera)		One small specimen											
Beetle (Coleoptera)		2	0.14	7	0.1	20	1.9	2	1	66	0.25	12	13.1
Flies (Diptera)		2	0.4	7				One Rhagionidae					
Other Aquatics: Shrimp (Amphipoda)		26	3.3	38	0.55	45	10.2	2	0.7	33	0.1	8	5.3
Sow bugs (Isoptera)		2	0.2	14	0.05	14	0.9						
Fish eggs (Grayling)								30	5.7	33	0.6	33	31.6
Algae				36	0.55	58	10.2						

no open season. In the spring of 1935, when the writer visited the lake, the fish were in poor condition and obviously hungry. Very few food organisms of any kind were observed and there was an almost complete lack of vegetation.

The stomachs of six grayling from this lake contained 52.5% debris. The aquatic insects were represented by only two groups: midges which accounted for 39.4% and mayflies which made up 10.5% of the total weight of food organisms taken (see Table 2). Terrestrial insects (all Coleoptera) constituted 13.1% of the total food, while amphipods were present to the extent of 5.3%. The item of grayling eggs (31.6%) seems large, but is entirely the result of conditions at the time of capture. With the very limited area for spawning, there is great wastage of eggs in this lake. Many are eaten by the fish that spawn them.

COMPARISON BETWEEN THE FEEDING HABITS OF GRAYLING AND TROUT

There is great similarity between the feeding habits of grayling and cutthroat trout. Specimens of both these species taken from Grebe Lake on the same date had the same kinds of organisms in their stomachs. The percentages of the food items in the two species were somewhat different but not more so than between any two grayling or any two trout. Damselflies made up 60% of the stomach contents of the cutthroat trout and about 20% of those of the grayling, while midges amounted to 6% of the cutthroat's diet and 40% of the grayling's. Hazzard and Madsen (1933) list the aquatic food of 40 cutthroat trout from Glacier National Park lakes as 92.4% and the terrestrial as 7.6%. In Rogers Lake, which is near and similar to the above lakes, 21 of the larger grayling contained 93.9% aquatic organisms and 6.1% terrestrial. Mayflies and shrimps were the most important items in the cutthroat trout diet, while shrimps and midges were the major items in that of grayling. The ratio of aquatic to terrestrial foods for 40 Meadow Creek grayling was about 78%:22% and for the 36 cutthroat trout from Teton Park streams (Hazzard and Madsen, 1933), 75%:25%. Most of the food items, exclusive of fish and other vertebrates, recorded as staple for cutthroat trout are also important in the grayling diet.

A comparison was made between the feeding habits of grayling and the trout (rainbow, brown, brook) in Meadow Creek. Stomachs of all these species taken on the same day showed a complete replication of items. The proportions of the various organisms varied between species and among individuals within the species but not in such a way as to indicate a difference in selection. Coston, Pentelow and Butcher (1936) point out that the European grayling has exactly the same food requirements as trout. They list insect larvae, shrimps, snails, ephemerids, caddisflies, and smuts as characteristic food items.

None of the specimens studied had fish in their stomachs, although several hundred trout and sucker fingerlings were seined from some of the same pools in which certain of the larger grayling were caught. Most of the organisms found in the trout stomachs were aquatic. *Daphnia* was the largest single item in the two brook trout,

damselflies in the three rainbow trout, and the isopod, *Asellus*, in the five brown trout examined. Three of the brown trout also contained snails (*Physa*), an item which was not found in any of the other fish.

Two doubles, each consisting of a grayling and a brown trout were taken on two "Cahill" flies and their stomachs saved for separate study. The organisms found in the stomachs of these four fish (see Table 4) are almost equivalent to a random sample of the most available food species taken from Meadow Creek on the same date. While Cladocera were not present in these particular brown trout, they were found in other specimens of this species taken about the same time. The other differences in the stomach contents are certainly not significant when individual variation is considered.

TABLE 4

A COMPARISON BETWEEN THE STOMACH CONTENTS OF TWO DOUBLES, EACH OF A GRAYLING AND A BROWN TROUT, CAUGHT BY FLY-CASTING IN THE MOUTH OF MEADOW CREEK—JULY 10, 1936

Kind of Organism	Double		Double	
	Grayling 335 mm. Standard L.	Brown Trout 300 mm. Standard L.	Grayling 310 mm. Standard L.	Brown Trout 386 mm. Standard L.
Snails (Physa)				7
Waterfleas (Cladocera)	15			
Shrimps (Amphipoda)			1	1
Sow Bugs (Isopoda)	1	5		
Mayflies (Ephemeroptera)	1	1		
Damselflies (Zygoptera)			1	
Caddisflies (Trichoptera)			2	
Bugs (Corixidae)	1	1		
Beetles (Dytiscidae)	2	5	9	1
Midges (Chironomidae)	3		1	2
Fly (Anthomyiidae)			1	
Plant roots				2

It is quite evident from the records of Metzelaar (1929) and others that the larger trout and grayling are not very selective in their feeding habits. The kinds and abundance of different organisms in the diets of these fish are determined by the size of the fish taking the food and the availability of the food species. The availability of food species is determined by the habitat and season of the year. Because a certain organism is consistently found to make up a part of a fish's food does not necessarily mean that the fish selected it in preference to something else. In order to test selection, all items must be present in equal numbers.

Bottom and plankton samples taken on the grayling waters mentioned above indicate that the invertebrate food items of grayling are roughly proportional to their relative abundance. The season of the year and the habitat of the fish almost certainly have greater influence on what is eaten than any selection these fish have demonstrated by their stomach contents.

There can be little doubt but what trout and grayling are natural competitors. The introduction of nonendemic trout into grayling waters certainly has contributed to the decrease of the grayling. A list of our present successful grayling waters includes only those which are free or nearly free from such trout. On the other hand, the grayling and cutthroat trout, which together originally occupied certain Montana waters, are compatible today in the successfully stocked Georgetown, Rogers, and Grebe lakes. Under present conditions in many places where rainbow, brown, and brook trouts have been introduced, the cutthroat as well as the grayling has almost completely disappeared.

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ORGANISMS OF A MALARIAL TYPE IN RUFFED GROUSE, WITH A DESCRIPTION OF THE SCHIZOGONY OF LEUCOCYTOZOON BONASAE[1]

C. H. D. Clarke

Leucocytozoon bonasae Clarke (1935b) described from the ruffed grouse has since been shown to be associated in its occurrence in the grouse population with cyclical mortality, and, among the diseases and parasites of the ruffed grouse is considered a possible cause of the cycle (Clarke 1935a). Concurrently with the description of *L. bonasae*, leucocytozoa were reported in the spruce grouse (*Canachites canadensis*), and have also been found in the sharp-tailed grouse (*Pedioecetes phasianellus*) by Saunders (1935), and in willow ptarmigan (*Lagopus lagopus*) by Allen and Levine (1935). They were found by the writer in rock ptarmigan (*L. rupestris*) in the Mackenzie District in 1936.

It has been my privilege to examine sections of various tissues of ruffed grouse collected at different seasons, to observe the morphology of the schizonts and merozoites of *L. bonasae*, and to get an idea of the nature of the disease itself. During the recent period of diminution of grouse, schizonts have been found present in all grouse old enough to show infection and at all seasons. Whereas the youngest grouse showing gametocytes were approximately three weeks old, in grouse at least as young as ten days schizonts have been found. Gametocytes have not been observed in the blood in winter, that is from about the first of October to the end of April

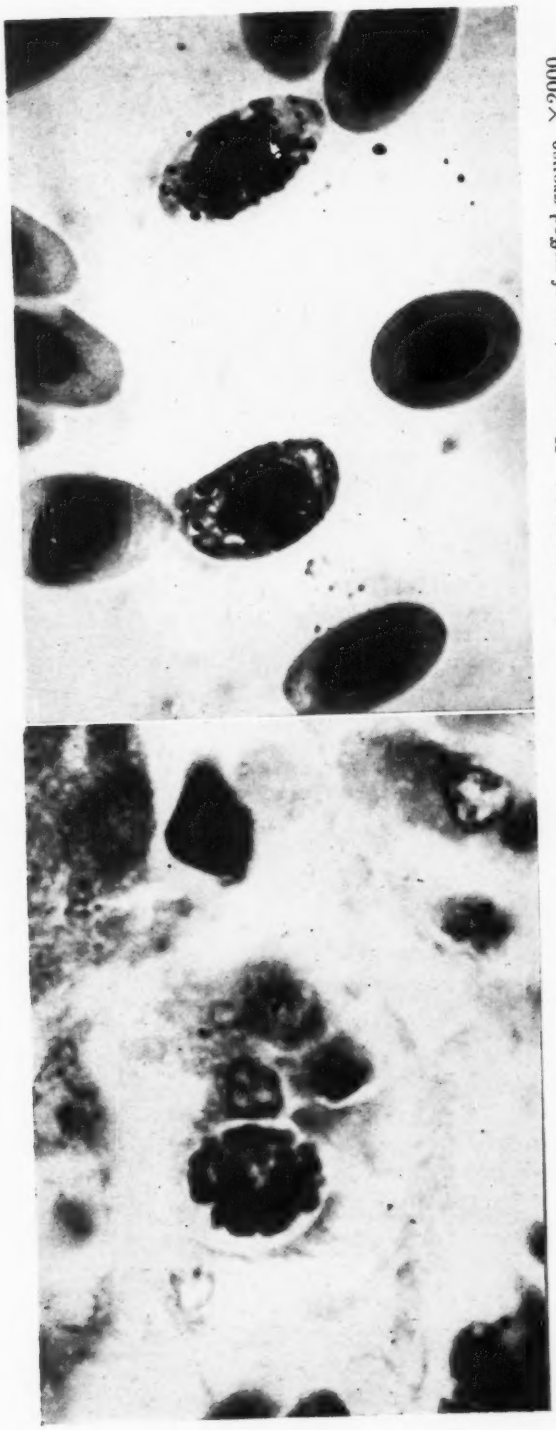
Differences in schizont morphology were noted. Some schizonts are larger than others, a condition probably due to multiple infection of a certain number of endothelial cells. The chief differences found in the grouse examined were in the actual numbers of schizonts, indicating the intensity of the infection. Schizonts in grouse taken in winter, when gametocytes are absent from the blood, were not numerous. They were small, without indication of double infections, and in some respects suggestive of cysts. In spring there appears to be something in the nature of a relapse in the disease, indicated by the reappearance of gametocytes in the blood, and by multiplication of schizonts. A few weeks later the young birds become infected and show schizonts. An excessive number of broken-down liver cells is associated with active schizogony.

Development of merozoites was found to be similar to that described for *Leucocytozoon anatis* by O'Roke (1934). Plate 7-A shows a schizont with fully developed merozoites. Shifting focus shows these to be slightly elliptical.

Schizogony

The relationship of schizonts and gametocytes with seasons and the age of the host is shown by their appearance in the stages described below, schizogony being compared in iron-haema-

[1] Prepared May 1936 from work carried out at the Dept. of Hygiene and Preventive Medicine, University of Toronto.



A (*left*)—Schizont of Leucocytozoon bonasae in liver of ruffed grouse. ×2000. B (*right*)—Haemoproteus of ruffed grouse. ×2000.
Left, macrogametocyte; right, microgametocyte.

toxylin stained sections of liver, and pigment in unstained sections.

Adults

1. Early in June. Before the young are hatched gametocytes appear in the blood of adults in small numbers. The liver at this stage shows a fairly heavy infection with schizonts. There is no abnormal amount of melanin present in the liver.

2. Late in June. At this stage there is a fairly large number of gametocytes in the peripheral blood. Schizogony, however, has dropped off. Pigmentation is not abnormal.

3. Mid-summer. Gametocytes have dropped off in number, and schizogony is not at all extensive. There is a large amount of melanin in the liver.

4. Late summer. Gametocytes are present in numbers similar to those of the summer stage. Schizonts have fallen to the winter level. Pigmentation is normal.

5. Early fall. Gametocytes are absent and pigmentation is normal. Schizonts are sparsely distributed.

6. Mid-winter. Similar to fall.

Special interest attaches to two winter specimens which had been captured alive in a wounded condition and kept till they died. In these a new schizogony cycle was just getting started, so that besides mature schizonts there were a number of immature, often in small groups. Some of the mature schizonts had ruptured. This is important with respect to the normal absence of parasite activity in the winter, since in these cases *Leucocytozoon* had renewed its activity at that season either as a result of lowered resistance of the hosts due to wounding, or to indoor temperatures, or both.

Young

1. Before appearance of gametocytes. Pigmentation is normal. With respect to schizonts two specimens about ten days old (guessed from development of feathering) showed differences indicating that one was infected with sporozoites earlier than the other. One had a fairly heavy infection with very immature schizonts, and the other had a heavy infection with the schizonts comparatively mature. One specimen around two weeks old agreed with the latter of these two.

2. At first appearance of gametocytes. Gametocytes are quite mature when they first appear in the circulation and are in large numbers. At this stage schizogony is less than in the preceding one, and the average number of schizonts is reduced. Pigmentation is normal.

3. Mid and late summer. Gametocytes persist in fairly high numbers throughout the summer in these young birds. Schizogony varies, in that there may be in some mid-summer specimens more large schizonts than at the time of first appearance of gametocytes. Towards the end of August, however, the number of schizonts falls off to the winter level. A large accumulation of melanin is present.

DISCUSSION

The conditions found may be interpreted by assuming that the presence of large numbers of schizonts including occasional large specimens is a sign of lack of resistance; the opposite condi-

tion indicates resistance, whether intrinsic to the host or conditioned by the environment, which cuts down the intensity of the schizont infection and the rate of development of schizonts. Accumulation of melanin is the result of the continued presence of a large number of gametocytes. Thus if many gametocytes are found in the absence of heavy pigmentation, then these gametocytes can not have been present long, and if a small number of gametocytes accompanies a large accumulation of pigment, then there must recently have been a larger number.

In the spring the resistance of adults breaks down. The over-wintering schizonts discharge their merozoites and new schizonts form, and there is a small number of gametocytes. Later on, a renewal of resistance cuts down the process of schizogony and throws a large number of gametocytes into the circulation. At a still later period both gametocytes and schizonts are fewer, but the presence of pigment shows that a large number of gametocytes had recently been present. As fall approaches schizonts assume their winter form and in cases where the number of gametocytes increases in late summer, the lack of pigmentation shows that they have not been present in great numbers in the period immediately preceding. Under special conditions, parasite activity may start in winter.

In young birds after infection, schizogony goes on for a while without gametogony. Then a degree of resistance is acquired, schizogony is reduced and gametocytes appear in the blood stream. Schizogony and gametogony fluctuate during the summer, until finally the winter condition is reached. The fact that the production of gametocytes in numbers is concurrent with a reduction in schizogony makes it evident that gametogony is a reaction of the parasite to resistance. The periodicity of gametocytes might be attributed to fluctuations in resistance and compared to the condition found by Mathis and Leger (1909) were it not for the finding of O'Roke (1934) that gametocytes of *Leucocytozoon anatis* were absent from the blood of ducks kept for the winter in Michigan, but present in those that migrated to Louisiana. It will be seen from the above that the absence of gametocytes is in no sense indicative of the absence of leucocytozoa from the host. The study of the schizogony is a necessary complement to the study of gametogony.

HAEMOPROTEUS OF RUFFED GROUSE

Haemoproteus not hitherto recorded from ruffed grouse was found in blood smears from two specimens collected at Pancake Bay, Algoma District, Ontario, during the summer of 1935. Identification of the species has been hindered by the fact that the original description of *Haemoproteus mansoni* Sambon from *Lagopus scoticus* has not been located. Fantham's (1910) figures are of very immature specimens, while those in Castellani and Chalmers (1919), stated to be after Sambon, are not accompanied by any mention of specific characters. They may represent immature stages of the *Haemoproteus* of ruffed grouse, but they certainly do not depict the characters of the majority of stages. Coatney and Roudabush (1937) consider that the parasite here described

may be *Haemoproteus velans*. In default of identification, a description of the gametocytes is given.

Both infections were quite heavy so that a large number of specimens were available. Individuals (Plate 7-B) from a fresh slide from the second grouse taken on August 24, 1935 are used for this description. Early stages are found in both sides and ends of the erythrocytes, the lateral situation being most common. Nuclei of mature forms are likewise to be found in any position, but as a rule are laterally placed. There is no enlargement of the host cells, and usually no displacement of its nucleus. In a large majority of cases the host cell nucleus was completely surrounded with the parasite closely appressed to the periphery of the host cell. In many instances a clear zone around the host cell nucleus could be seen, as though there was still a free area of host cell cytoplasm. A small number of examples were seen in which the two ends of the parasite did not meet and the host cell nucleus was pressed to one side.

The cytoplasm of the macrogametocyte stained a fairly deep blue with Giemsa and may be described as hyaline to alveolar. The nucleus stained red, is fairly compact and averages $3.7\mu \times 1.9\mu$ in size. The microgametocyte with Giemsa staining is very pale except for the rather diffuse nucleus which took on a good red coloration. It makes up around one half of the parasite and may be spread over one side and both ends, as viewed with the host cell nucleus centrally placed.

Schizonts were found in sections of liver and spleen, but since *Leucocytozoon bonasae* was also found, both species were obviously represented. Schizonts were examined carefully, and while differences were found in them, they were no greater than those found in a simple *L. bonasae* infection; there were not two groups assignable on sight to two species.

It is impossible to make any definite statement concerning the effect of *Haemoproteus* on the grouse. Organisms of this type can be pathogenic (O'Roke 1930). It may be said, however, that these were the first *Haemoproteus* infections found in Ontario grouse, whereas every grouse examined in 1934 and 1935 was infected with leucocytozoa. This scarcity is probably related to the fact that hippoboscid flies have not been found commonly on Ontario grouse.

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A (*left*)—Pisgah portable deer trap.
B (*right*)—side view; arrow indicates junction of the sections.

TRAPPING DEER ON THE PISGAH NATIONAL GAME PRESERVE, NORTH CAROLINA

Frederick J. Ruff

Trapping of adult deer on the Pisgah National Game Preserve was initiated in 1928 for two purposes: to supply animals for stocking other game refuges in the South, and to help reduce the rapidly increasing number of deer on the Preserve. The first purpose has strongly overshadowed the second for, as yet, it has been impossible to intensify trapping to the point at which the catch would counterbalance natural increase.

At the outset, trapping was purely experimental in nature. Large corrals with attached chutes were used, and a concealed observer released the gates by cutting a supporting wire. This method was highly inefficient because of its cost of operation, and of the losses of panicky deer that killed themselves in stampeding against the sides of the corral.

During the second year of trapping, an automatic release was used on the chute and in 1934 Warden Clyde Case built and tested the forerunner of the present trap. This differed from the original in that the large corral was reduced to a mere screened approach to the chute, and all gates were operated by automatic releases. The advantages of this smaller trap were its lower cost of construction, restriction of the movements of a trapped animal, and portability. The installation of automatic releases obviates the need of an observer for each trap.

Since the initiation of this form of deer utilization, 656 trapped animals have been shipped from the Pisgah Preserve. Although these were largely adults, many were fawns not over 5 or 6 months old. Of this total number, 242 were shipped during the 1936–37 trapping season, and 253 during that of 1937–38. During this last period, 164 traps were operated, on the basis of which the season's catch averages approximately 1.5 deer per trap. Although proper regulation of the numbers of deer may never be possible through trapping alone, this activity is to be continued intensively as a permanent project.

The Trap

The portable trap (Plate 8) is about 4 feet wide at the widest part and 16½ feet long, the screened approach and the tapered chute both being of about equal length. Dimensions and details of construction are given in Figures 1–4.

The trap is designed to work with maximum efficiency and the least danger of injuring the catch. As efforts to entice deer directly into a chute have not met with great success, a screened approach is necessary. The approach must be constructed sturdily even at a slight sacrifice to diminution in bulk. Fox-wire of one-inch mesh has proved most satisfactory because the mesh is not so small as to make the wire glaringly conspicuous, nor so large that a deer may injure itself by thrusting its snout through it. Wire galvanized after

weaving is far more rust-resistant than that which has been galvanized before it is woven.

Drop gates must be carefully constructed so that they will close with the greatest possible speed, and with a minimum of scraping and jarring. They must fit loosely enough to allow for sense of sight, and is inhibited to the degree to which the use of this is impeded. The question of the presence of sufficient air inside the closed chute is of minor importance. Even though dressed lumber may be fitted tightly enough to exclude some air, the gates will not close sufficiently snug to pre-

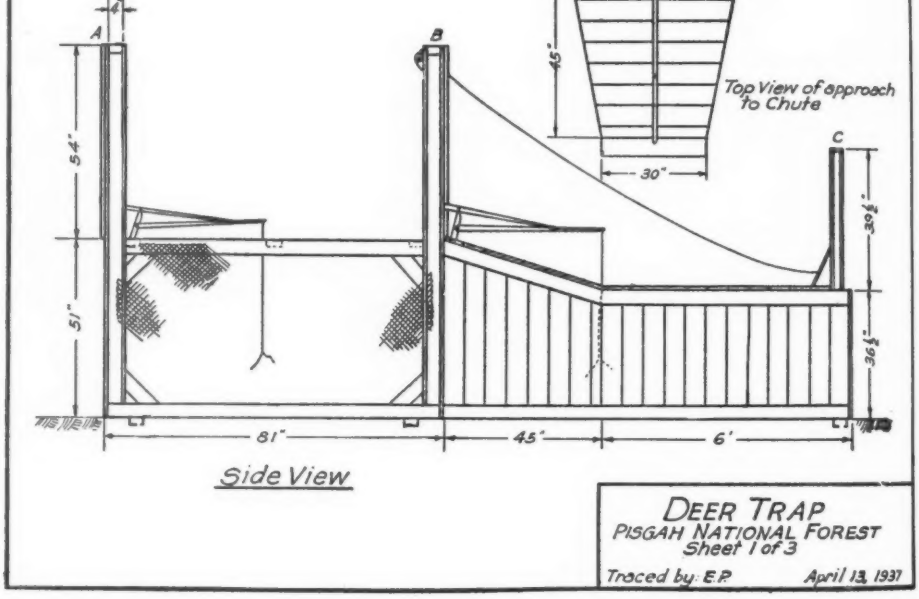

Fig. 1.

swelling of the lumber during periods of wet weather, but yet not so loosely as to give a trapped animal cause for persisting in attempts to escape.

The chute should be constructed so that light is practically excluded from the interior. The more nearly total darkness is maintained after the deer is confined, the more quiet the animal remains; for it depends strongly on its vent the passage of more than enough.

Every part of the inside of a completed trap should be very carefully inspected for obstructions on which a deer might injure itself. Splinters and broken boards should be removed or mended and nail heads or points hammered down so that a smooth and uninterrupted surface remains.

Two types of triggers or automatic

gate releases are being used, each having its advantages and disadvantages. The original figure-4 trigger (fig. 3) made of wood has been satisfactory in that it could be set so that only a deer could release it. It does not however react with the greatest efficiency to the pressure of an animal on the release-wire, nor will it function with the same degree of pressure at all times. The mere variation of the angle at which the trigger assembly is placed against the drop gate will cause marked difference in the amount of pressure required to release it. Climatic changes also affect its functioning; after a protracted rain, it may be useless until dry again.

The second, or metal-bar type of trigger (fig. 4) that is now replacing many of the figure-4 type, has been much more satisfactory in the ease with which it can be released, the degree to which it conveys pressure on the release-wire to the release-bar, and its response, after initial adjustment, to practically the same pressure regardless of how it may be set. The release-wire must be set so close to the ground, however, that practically any species of wildlife may spring the trap. Unless the release-wire and trigger assembly are raised higher above the ground by the use of lateral supports on the screened approach, a little inconvenience will be experienced in the early part of the

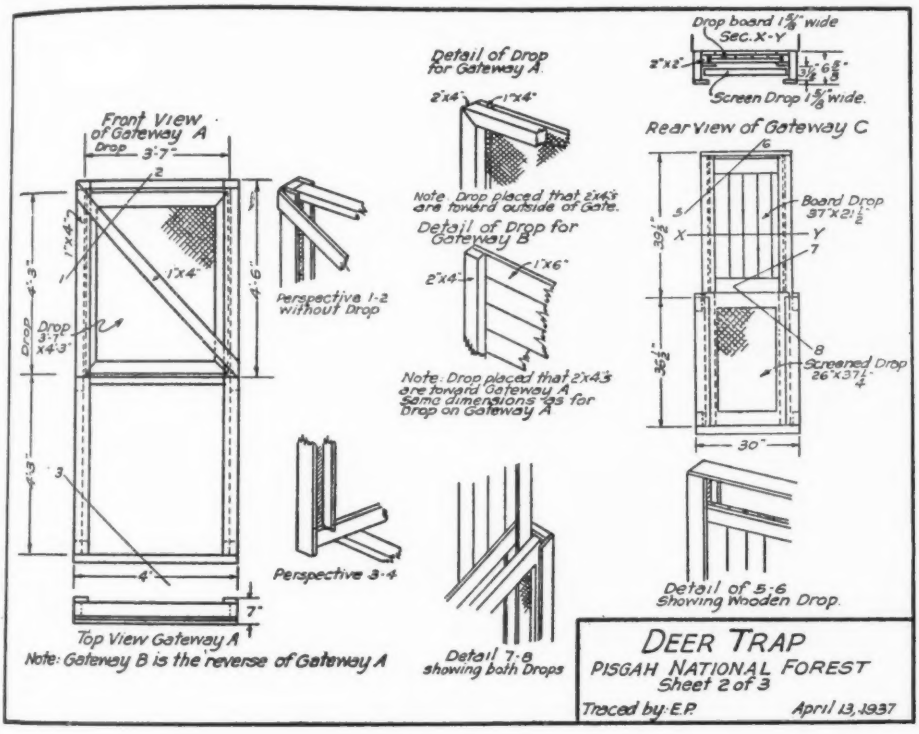
Front View of Gateway A
Drop 3'-7"
Perspective 1-2 without Drop
Perspective 3-4
Top View Gateway A
Note: Gateway B is the reverse of Gateway A
Detail of Drop for Gateway A
Note: Drop placed that 2x4's are toward outside of Gate.
Detail of Drop for Gateway B
Note: Drop placed that 2x4's are toward Gateway A Some dimensions vary for Drop on Gateway A
Detail 7-8 showing both Drops
Drop board 1 5/8" wide Sec. X-Y
Screen Drop 1 5/8" wide.
Rear View of Gateway C
Board Drop 37"x2 1/2"
Screened Drop 26"x37 1/4"
30"
Detail of 5;6 Showing Wooden Drop.
DEER TRAP
PISGAH NATIONAL FOREST
Sheet 2 of 3
Traced by: E.P.
April 13, 1937

Fig. 2.

trapping period before lesser but more common and inquisitive animals have learned to keep away.

A slight modification of the trap is necessary if the metal-bar trigger is to be used. When a gate of the standard trap is raised into position to be released, its upper edge touches the upper

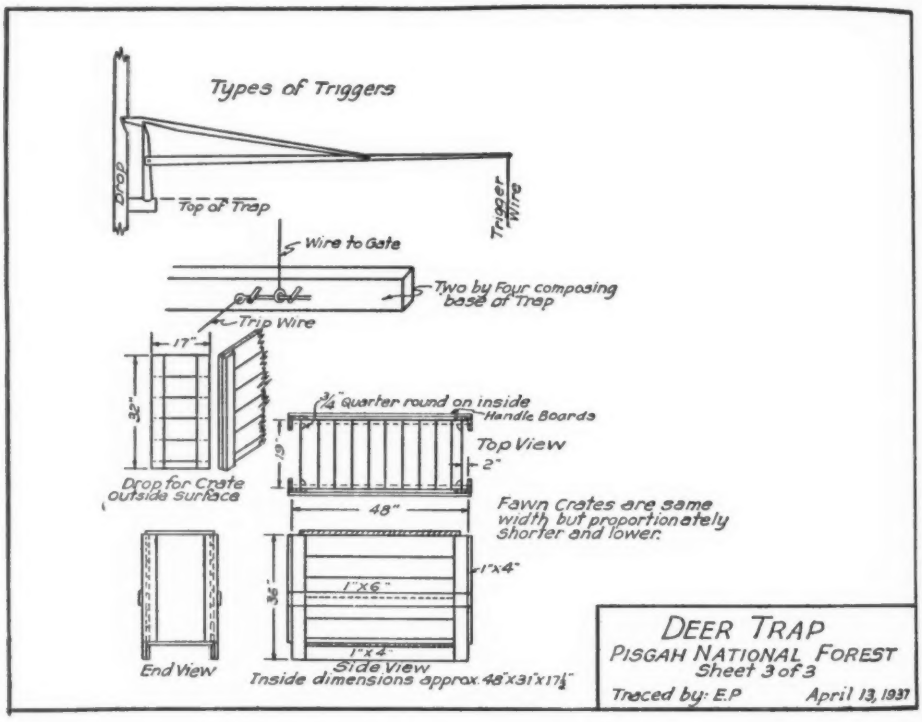

Fig. 3.

horizontal brace of the gate-guides. No space therefore remains in which to hang a pulley or, as is being used on the Pisgah, a telephone line split-tree insulator. Such objects placed beneath this upper brace cause the gate to hang appreciably lower than is desirable for maximum efficiency. This can be remedied either by raising the upper gate-guide braces 6 to 8 inches above their present level, or by fastening on them an inverted U-shaped structure of 2″×4″ lumber about 6 to 8 inches high and 8 inches wide from which the pulley may be hung.

Materials for the triggers should be selected with care, for a large part of success in trapping depends on proper functioning of the release mechanism. Hard wood that swells the least when wet is the most desirable for the figure-4 triggers. If galvanized iron or other rust-proof metal can not be obtained for the metal trigger, care should be taken that all sliding parts are kept clean and protected with a little oil.

When using the metal-bar trigger assembly, special attention must be

given to selecting and arranging the wire or cord that supports the drop gate in the open position. Heavy insulated copper telephone wire has been found best, as both cord and ordinary uninsulated copper wire stretch and must be adjusted repeatedly. As the length of the wire is determined by the distance from the trigger, through the pulley, to the top of the gate, complete closing of the gate will pull the end attached to the trigger through the top of the trap. It is therefore necessary to fasten a small loop or ring to this end,

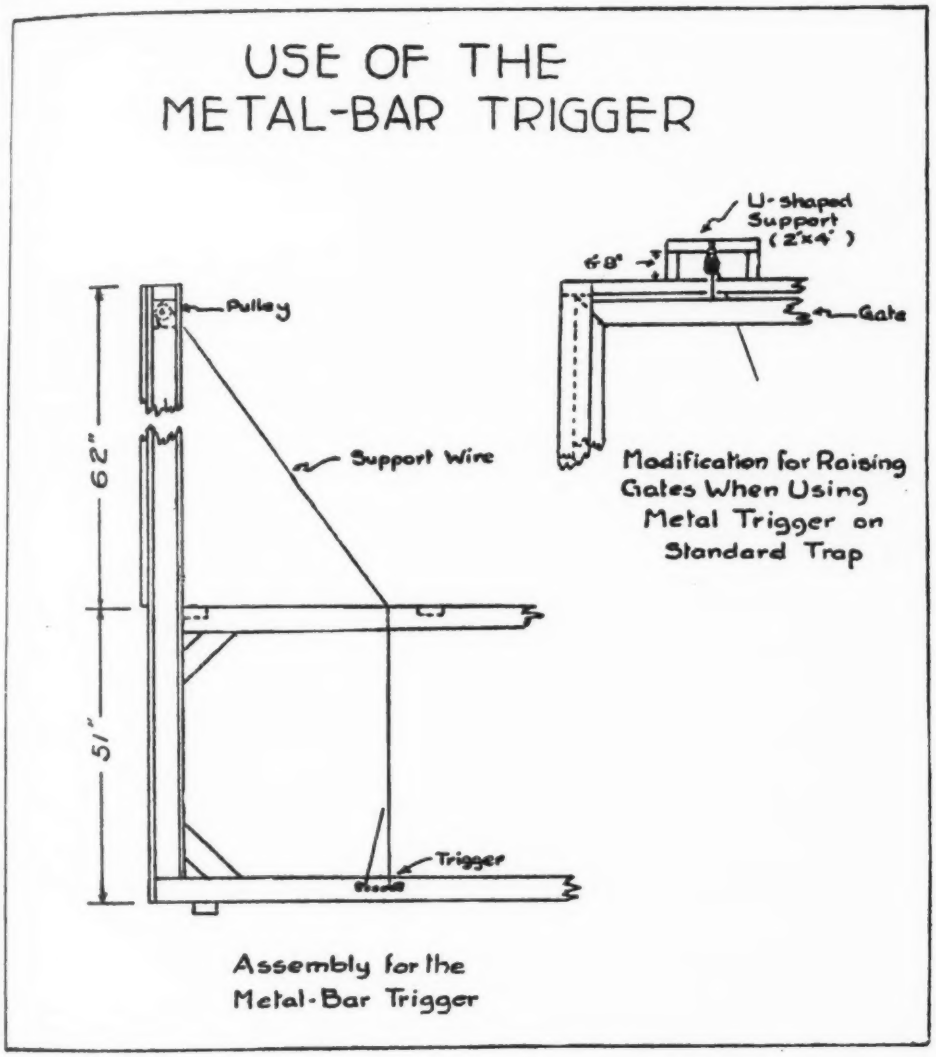

Fig. 4.

so that the wire will slip easily from the trigger-bar and pass through the trap without hooking on any obstruction. Such a ring can be made of heavy galvanized wire, or formed by simply looping a few turns of the cleaned copper wire. A similar loop should be made on the end of the trigger-release wire which extends across the interior of the trap.

CONSTRUCTION OF THE TRAP

Materials for building the portable trap cost between $15 and $16. One maintained properly should last six years, if not longer. Construction cost can be reduced appreciably by using salvage lumber. Although the bill of material on pp. 159–161 is recognized as standard, modification can be made to fit available scrap lumber without reducing the efficiency of the structure.

Traps should be built in two sections: the chute proper and the approach. These can then be nailed together at the time they are placed in position, or fastened by means of the ordinary hook and eye.

Staining a newly constructed trap is advisable, but should be done well in advance of the season so that the odor of the preservative may be thoroughly dissipated. Staining or painting, aside from preserving the trap, makes it less conspicuous. Ordinary creosote stain has been found most satisfactory, but green or drab paint is almost as desirable.

THE SHIPPING CRATE

Figure 3 illustrates the standard deer shipping crate used for deer averaging approximately 130 pounds in weight, and rarely exceeding 200 pounds. The construction of this crate requires no extra explanation; the same care used in building the chute should be used in reducing as much as possible the amount of light entering it, and in eliminating all obstructions.

Special modifications of the crate may be advisable to facilitate tagging or liberating the animal. A board at each end of the top may be hinged and fastened with a screw or hasp. This would allow one to reach into the crate over the head of an animal. The sliding gate, standard for the entrance to the crate, may be duplicated in construction on the other end so that when an animal is liberated it will not attempt to turn inside the crate, or be forced to leave it backwards. A crate costs approximately $2 and is usually considered expended after shipment.

If trapping becomes intensive it may be necessary to place traps at considerable distances from roads. Under such circumstances a convenient method of carrying a loaded crate is necessary. A welded strap-iron basket fitted so as to hook to two long carrying-poles facilitates transportation, but adds a cumbersome piece of equipment to the operations. Practically the same ease of handling can be attained by hooking the handle-board of the crate into two strap-iron hooks fastened to a carrying-pole.

THE OPERATION OF THE TRAP

The operation of the trap is based on the ordinary principles of the "catch-alive" traps used for other wildlife, with the exception that the animal must be confined in a darkened enclosure as quickly as possible. After a deer has released the screened gate of the

approach, it generally thrashes about a little in an effort to escape the way it entered. Finding this entirely closed, it makes a dash for the supposed opening at the far end of the chute. In this effort it releases the chute gates, and then gradually becomes quiet in the gloom of the closed chute. Most animals seek egress along the bottom of the trap; hence no noticeable holes or openings should be present, and gates should close snugly to the ground. Several broken legs have resulted from the persistent attempts of deer at forcing an escape through such holes.

The help of two men is generally needed in setting the release mechanism. A figure-4 trigger that has swelled should be carefully tested, and replaced with a new one if found unsatisfactory. A metal-bar trigger that has rusted should be scraped clean and oiled well, so that all parts move against each other with the least amount of friction. Experience in setting will develop judgment in the trappers so that they will adjust triggers to respond to a minimum of pressure, and will set gates open as wide as possible. Care in setting the figure-4 trigger should be exercised so that pressure on the release wire is not all expended in overcoming intermediate friction before it is transmitted to the trigger arm.

A trap should be baited in a way that will lead an animal into the approach rather than feed it on the outside. Deer will eventually inspect a trap out of curiosity. It is not necessary to scatter a large amount of bait about the entrance. A few sprigs of a common, relatively palatable, evergreen shrub may be thrust into the ground to conceal the release-wire, which, in itself, should be as inconspicuous as possible.

Several types of bait have been tried with success on the Pisgah. Apples, both the cultivated types and crab apples, have so far been most satisfactory. Corn, cabbage, and other garden crops have also been successful in areas where deer had been accustomed to making nightly raids on garden patches. After the first of January, the common, but relatively unavailable winter forage, the rhododendron proved to be an efficient bait.

Bait will vary with the region, for it must consist of palatable forage to which the animals have been accustomed, or which is sufficiently similar to such forage that it will soon be recognized as edible. In Florida, for instance, a bait of salted peanuts has been found very attractive. A little experimentation should result in selection of the most efficient bait.

CRATING, SHIPPING, AND RELEASE

Crating an animal requires a little practice. After the crate is placed at the rear of the chute ready to receive the trapped animal, the screened guard-gate, behind the solid chute-gate, is removed, then the chute-gate is raised. Ordinarily, the deer will make a dash for the crate, but a little coaxing may be necessary from the direction of the approach. This is best accomplished by waving a switch in the chute from beneath the slightly raised middle gate. When the animal is secured in the crate, the door may be held fast with two partly driven nails which can be removed easily at the point of release.

A crated deer should be shipped as soon as possible in order to minimize

the evil effects of confining the animal with neither food nor water. A half-ton pickup truck is the most efficient transportation equipment for taking crated deer to the railhead or destination; and it can haul a maximum of four loaded crates at one time.

Deer must frequently be shipped by rail. Under such circumstances they should be sent by express via the shortest route. Crated animals may be able to remain in good health as long as 48 hours without food or water, but 36 hours should be considered the maximum time of confinement.

Releasing a deer should be done with the least amount of noise or disturbance; and visitors, if permitted to witness the activity at all, should remain quiet far from the point of release. The excitement of undergoing such unusual handling leaves the deer in a high state of nervous tension and any small disturbance may make it panicky, and either cause it to injure or kill itself in stampeding into an obstruction, or to die from heart failure.

It may be desirable to tag a trapped deer. This operation is best conducted when the animal is in the crate. By removing a board of the top, on the end nearer the animal's head, and blindfolding the animal quickly with a black cloth thrown over its head, an ordinary sheep-tag may be fastened to the ear. With practice, this operation can readily be accomplished.

Weighing crated animals is best accomplished by weighing them in the crate and then subtracting the predetermined weight of the crate. This may not be absolutely accurate because of slight variation in the crate due to absorption of moisture; but it fulfills all practical requirements.

PROCEDURE AND ORGANIZATION OF TRAPPING

Trapping should be confined to the period between October 1 and April 15, or as near these limits as the habits of the deer dictate. Between April 15 and October 1 trapping has never been successful on the Pisgah due to the available summer forage, but it is also the time during which does are either heavy with fawn, or are raising them. After the first of October practically all fawns are weaned.

The size of the trapping crew depends upon the number of traps in operation, and their accessibility. On the Pisgah, two men can successfully operate 60 to 75 traps. This includes daily inspection, proper maintenance of each trap, and shipment of the catch. Whenever possible, however, the help of additional personnel may be used in expediting the work. For instance, when deer are being shipped to neighboring game refuges and truck transportation is being furnished, the personnel engaged in such transportation may well run on a schedule and help in the trapping operations until they are ready to return with a load of deer.

A few hints on the general procedure of trapping may prove valuable. Careful consideration should be given to placing a trap level enough to allow the gates to close easily and rapidly. The best locations have been found to be comparatively level clearings and open fields, a slight distance away from brush and cover. Regardless of how conspicuous a trap may appear, deer soon become accustomed to its presence;

and as it becomes weathered, they lose their apparent dislike for it and begin visiting it. Numerous catches have been made, however, with traps hardly a day old. Though deer are generally caught at night, a few catches have been made during the day.

Bucks with large antlers are occassionally caught in a trap. Ordinarily such animals do not attempt to enter the chute but remain in the screened approach. They should be liberated as soon as possible, before they injure themselves too much. An attempt was once made to saw the antlers from a large buck, but the operation caused the death of the animal through fright.

Often a deer, more wary than others, will visit the trap repeatedly without touching the release-wire. Changing the position of the wire a little then usually results in a capture.

As trapping proceeds, a definite relation will become evident between weather changes and the size of the catch. Deer will generally feed freely immediately preceding approach of inclement weather. Furthermore, during a protracted period of mild weather, the results of trapping will be disappointing.

At the close of the trapping season, traps should be raised from the ground, and the gates propped partially open. Those requiring it should at this time be creosoted or painted.

CONCLUSION

The Pisgah portable deer trap has been exceptionally successful, but is by no means the final word in deer trapping. The major consideration in its construction, aside from an attempt to capture as many deer as possible, has been to prevent injury to trapped animals. Less than 1 % of the deer caught are seriously injured. During the past year only two of 253 deer were fatally injured. The others were all released in excellent condition.

The development of this trap is still proceeding with the purpose of reducing bulk and still retaining existing advantages of efficiency and simplicity. Several types of entrance gates have been tried, as well as camouflage of the chute as seen from the entrance, to eliminate the ominous appearance of the tunnel. As yet such modifications make the structure more complicated; but they have possibilities and may eventually be developed into valuable improvements on the present trap.

Aside from the deer, almost every other species of wildlife and domestic animal has been caught. Foxes, raccoons, and skunks generally dig under the trap before morning. Bears emerge in whatever manner strikes their fancy. But chickens, dogs, grouse, hogs, cows, owls, hawks, and the apple-loving farmer's boy must await the pleasure of the trapper.

BILL OF MATERIAL[1]

I. TRAP APPROACH SECTION
(Including tapered portion of chute.)
A. Hardware, exclusive of nails.
3 pcs wire, hexagonal, 1″ mesh, 16 gauge, 4′ height, galvanized after weaving, 8′ long.
1½ lbs. staples, ¾″ No. 14 galv. wire.

[1] All specifications make liberal allowance for trimming.

B. Lumber (dressed 4 sides).

4 pcs 2×4×8′6″, drop guide, end
2 pcs 2×4×6′9″, approach frame
2 pcs 2×4×6′2″, approach frame
7 pcs 2×4×4′0″, cross braces
8 pcs 2×4×1′0″, corner braces
2 pcs 2×4×4′8″, frame of tapered chute section
2 pcs 2×4×4′3″, frame of tapered chute section
2 pcs 1×6×4′0″, top of tapered chute section
2 pcs 1×6×3′8″, top of tapered chute section
2 pcs 1×6×3′4″, top of tapered chute section
2 pcs 1×6×3′0″, top of tapered chute section
1 pc 1×6×2′8″, top of tapered chute section
8 pcs 1×4×8′10″, drop guides, lateral
2 pcs 1×4×6′3″, diagonal drop guide braces
4 pcs 1×6×4′3″, sides of tapered chute section
4 pcs 1×6×4′0″, sides of tapered chute section
4 pcs 1×6×3′9″, sides of tapered chute section
4 pcs 1×6×3′5″, sides of tapered chute section
2 pcs 1×4×3′2″, sides of tapered chute section

II. CHUTE PROPER

A. Lumber.

4 pcs 2×4×6′0″, frame
1 pc 2×4×2′8″, cross brace
2 pcs 2×2×6′4″, drop guides, end (solid gate)
4 pcs 1×4×6′4″, drop guides, lateral (solid gate)
2 pcs 1×4×3′1″, drop guides, (screened gate)
1 pc 1×4×2′7″, top of drop-guide assembly (solid gate)
26 pcs 1×6×3′1″, sides of chute
12 pcs 1×6×2′7″, top of chute

III. DROPS

A. For Gateway A.

1. Hardware.

1 pc wire, hexagonal, 1″ mesh, 16 gauge, galvanized after weaving 4′×4′1″

2. Lumber (dressed 4 sides).

2 pcs 2×4×3′7″, drop ends
2 pcs 2×4×4′3″, drop sides
2 pcs 1×4×3′7″, drop ends
2 pcs 1×4×4′3″, drop sides

B. For Gateway B.

1. Lumber

2 pcs 2×4×4′3″, drop sides
9 pcs 1×6×3′7″, drop ends

C. For Gateway C.

1. Lumber

2 pcs 2×4×27″, screened drop
2 pcs 2×4×38″, screened drop
2 pcs 1×4×23″, solid wood drop
6 pcs 1×4×37″, solid wood drop

IV. SHIPPING CRATE

(Lumber dressed 4 sides)

A. Crate Proper.

6 pcs 1×6×19″, top
2 pcs 1×4×19″, top
8 pcs 1×6×19″, bottom
10 pcs 1×6×48″, sides
2 pcs 1×4×48″, sides
4 pcs 1×6×35″, side braces
2 pcs 1×4×48″, carry boards
4 pcs 1×4×30″, drop guides

B. Crate Drops.

4 pcs 1×6×17″
10 pcs 1×4×17″
4 pcs 1×6×32″

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A RAPID METHOD OF CROSS-SECTIONING MAMMALIAN HAIRS

Harold A. Mathiak

Identifications of hair samples are a frequent need in connection with life history studies, food habits research, and investigation of isolated cases of mortality in the field. Cross sections of hairs often prove of material value in determining the identity of the mammal involved. In some mammals, for example the shrews, the shape and structure of the cross sections of the hairs are much more distinctive than the appearance of the hair as viewed longitudinally. Especially is this true when it is known from which part of the hair the cross sections are obtained.

Several methods of cross-sectioning hairs have been used in the past, the most intricate being the use of rotary or sliding microtomes. However, many workers do not have access to microtomes, and furthermore, the amount of time required by the microtome method[1] is far too long for practical purposes. Hardy (2) mentions Hotte's method of building up successive layers of celloidin, bayberry wax, and paraffin about individual hairs in order to section them. Dearborn[2] rolled softened paraffin between the palms of the hands forming a cylinder. The cylinder was cut lengthwise, hairs were inserted between the halves which were firmly pressed together again, sections then being sliced with a razor blade.

Williams (3) describes a method developed and used at the Food Habits Research Laboratory, Denver, Colorado, by which individual hairs can be sectioned. The pith from the stem of a plant, such as ragweed, is split lengthwise, and the hairs are placed between the halves parallel to the longitudinal axis. The halves are sealed together with gum-arabic mucilage which is allowed to dry. Sections are then cut with a sharp razor blade. These sections can be mounted in Canada balsam for microscopic examination.

Recently an efficient, modified microtome with which an experienced operator can obtain cross sections of fibers in ten minutes was invented by Hardy (2). A group of fibers is washed in alcohol or ether, dried with blotting paper, and placed in a rectangular slot in a holder of the metallic device including a finely threaded screw by means of which the clump of fibers can be projected through the slot any desired distance. Colored celluloid solution is applied to the ends of the fibers and allowed to dry, after which the sections of the celluloid and fibers are cut off with a sharp razor blade and mounted in Canada balsam.[3] The instrument was intended primarily for the study of fibers used in the textile industry and is admirably suited for that purpose since large numbers of cross sections of each

[1] This method is discussed in detail in Guyer's (1) Animal Micrology.

[2] From verbal description of the method by H. M. Wight.

[3] Diagrams and a more complete explanation of how the device operates are to be found in Circular No. 378, U. S. Dept. Agriculture (2). This instrument is now available at a price of $35.

sample of fibers are wanted. Sections may be cut so thin that even the shape of pigment granules can be seen.

In the course of his studies the writer has developed another technique for cross-sectioning hairs which seems satisfactory. It works equally well for one or several hairs of any size. They are visible during the entire operation so that cross sections of any desired portion of a single hair can be taken. Guard hairs exhibit much more individuality than fur hairs, and since the shape of the cross sections of guard hairs may vary widely from base to tip, it is essential that the region be known from which the cross sections are cut.

The method is inexpensive, requiring razor blades, a pink solution of celluloid in acetone, and balsa wood, the latter purchasable at stores carrying model airplane supplies.[4] While different pieces of balsa wood may vary in hardness, none are too hard to cut with a razor blade. For use in sectioning small hairs individually, the long strips of wood can be cut into sticks about four inches long and halved longitudinally.

In making the celluloid solution, first dissolve a red or pink dye (as these colors apparently give the best results) in acetone, and then add pieces of celluloid until the solution is of the right consistency. There can be considerable range in viscosity, thin solutions having the advantage of evaporating faster and thicker solutions of holding the hairs more firmly. The solution should be colored only a very pale pink, for the dye will become more concentrated when the acetone is allowed to evaporate. Too much dye in the celluloid interferes with transmission of light and reduces definition. Congo red, carmine, or any red dye is suitable. Dyes not soluble in acetone can be added after being first dissolved in alcohol. The celluloid solution is most conveniently kept in a small, tightly stoppered bottle in which a brush is attached to the stopper. Finger-nail polish can be substituted for the celluloid solution by those wanting to section only a few hairs.

Imbedding is accomplished by placing a coating of celluloid on a stick of balsa wood, and then laying the hairs on the sticky solution parallel to the long axis of the stick as shown in Figure 1, A. Additional celluloid is placed on top of the hairs and allowed to dry. The sections can be sliced in from five to ten minutes, depending on the amount and viscosity of the solution used. Hardening of the celluloid can be hastened by mildly heating it over an electric lamp after most of the acetone has evaporated. Heat should not be applied immediately because it causes the formation of large bubbles. No time will be lost waiting for the celluloid to harden if five or more samples of hair are imbedded before any sectioning is done.

A razor blade held in a vertical plane is used with a slicing motion to cut through the celluloid, hairs, and wood. Sections (shaped as in Fig. 1, B) can be varied from .3-1 mm. in thickness, .6 mm. being generally most suitable.[5] The sections are arranged in serial order on a slide and examined under a microscope with transmitted light. A thin

[4] In Ann Arbor strips of balsa wood $\frac{1}{8} \times \frac{1}{4} \times 18$ inches cost one cent each.

[5] Thinner sections seem to be better for either white or densely pigmented hairs.

film of oil on the slide will prevent displacement of the extremely light pieces of balsa wood. Long hairs can be cut into shorter lengths which, if imbedded in consecutive order, will give serial sections of the entire hair.

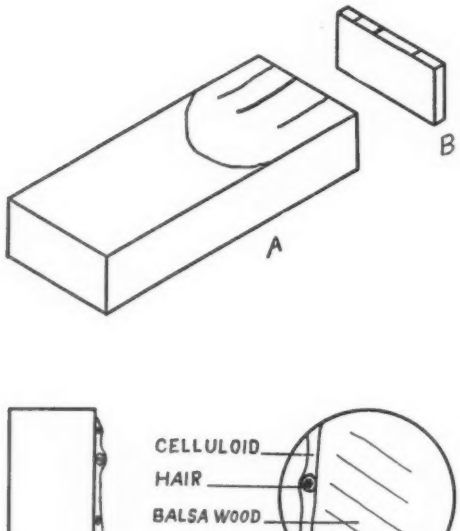

Fig. 1. A, Small stick of balsa wood showing hairs in celluloid, ×2; B, a section as cut off, ×2; C, same section ×3 with size of hairs exaggerated; D, diagram of a section as it appears in the microscopic field.

Although low power discloses structural features sufficiently well in most instances, high power can be used for the examination of the smaller hairs and in the event that measurements are to be taken with an ocular micrometer. Small hairs will be found imbedded entirely within the celluloid while very large hairs may appear to project above the general level (Fig. 1, C) since the solution greatly decreases in volume upon drying. In either case the celluloid is so rigid that cross sections are obtained without distorting the hair. The celluloid is colored a light pink to differentiate it from the wood and to improve optical effects. A brilliant illumination with the celluloid and hair to one side of the microscopic field, as shown in Fig. 1, D, gives the gives the best definition, the wood cutting out much of the light and preventing eye strain. Clearing the hairs with an oil is not necessary, the medulla, cortex, and character of the pigmentation being discernible in the sections as cut. Cross sections from specimens of known identity can be filed in small vials for future reference.

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SOME OBSERVATIONS ON ADAPTABILITY OF MICHIGAN BEAVERS RELEASED IN MISSOURI

Earl L. Atwood, Jr.

The writer believes the observations here recorded will be of interest to those whose knowledge of the beaver rests upon familiarity with the animal in its more northern haunts. There aspen is by far the most important food species, followed by birch, alder, wild cherry and willow, and occasionally oak and a few other species.

The population of the native beaver (*Castor canadensis missouriensis* Bailey) by 1927 had become so depleted that the animal was thought by many to be extinct. Bennitt and Nagel (1), however, reported a few colonies of native beaver surviving in northwestern Missouri as late as 1934. In 1928 two pairs of Michigan beavers, obtained by the Game and Fish Department, were released in Indian Trail State Park on a tributary of the Meramec River near its headwaters in the Ozark portion of the State. Soon afterward beaver cuttings were found along the deeper water behind an old masonry dam in the Meramec River a few miles below the point of release. In 1929 four additional pairs of Michigan beavers were obtained and penned in a spring branch in Indian Trail Park from which they escaped downstream to the Meramec River. Shortly afterward a small colony was reported also about four miles upstream from the original colony at a point in the river known as Dent's Ford.

According to Bennitt and Nagel, "in 1929, two females and a male from this introduced stock and the first year's progeny were captured and released near Montauk State Park on the (Survey Furbearers Mo. 1937, p. 138.) Current River."

Since 1929 beavers have been protected by State law and increase from the nucleus of six pairs of Michigan beavers with which these two streams have been restocked has been remarkable.

Numerous observations have been made, beginning in 1935, on the four colonies extending for a stream length of about nine miles on the headwaters and on a tributary of the Meramec River. Judging from the number of houses and bank tunnels found in the fall of 1937, the population was estimated at 70 animals. In that year beavers were reliably reported also at two points many miles downstream, the most distant being near Des Peres, 135 miles water distance from the original colony at Short Bend.

In addition a colony was reported, and visited by the writer, on a tributary of the Current River, 80 miles downstream from the original point of liberation at Montauk State Park in 1929. The greatest upstream movement from the first colony, on the Meramec was approximately 15 miles; no upstream movement took place on the Current River for reasons explained below.

Four of the five colonies visited are located opposite corn fields, where the animals feed, and it is possible that at the other colony a nearby field had in

the past been planted to corn. Certain other features of the colony sites are similar. They are in flood plains five hundred or more feet wide, which is comparatively wide for Ozark valleys. The length of the dams built, however, is rather short—varying from twenty-five to one hundred fifty feet, with only one dam of the latter length. The gradient of the streams at these sites is nearly the same and averages about fifteen feet per mile.

Several factors are apparently responsible for the present location of these colonies. After failing to maintain dams against high stream velocities during periodic floods in the headwaters they were driven farther down stream. It is probable that the present marked utilization of corn was developed as a result of a shortage of woody food. It is also possible that corn was attractive as a plant having a resemblance to saplings and abundant within the feeding range of the beavers at one of the first colonies. When forced by population pressure and food shortage to migrate downstream, it is possible that the beavers sought a new colony site similar to that from which they came.

Some of the beavers were fairly successful in maintaining houses in the deep water behind the masonry dam, but others after losing one or more houses at other colony sites in the spring high waters adopted the bank tunnel as their style of abode.

Another example of adaptability is shown by the rather lengthy list of plants used as food. Cuttings have been found on the following species:

Common Name	*Scientific Name*
Alder	Alnus rugosa
Dogwood	Cornus racemosa
	Cornus obliqua
Willow	Salix nigra
	Salix longipes var. wardii
	Salix interior
Red cedar	Juniperus virginiana
American elm	Ulmus americana
Cork elm	Ulmus thomasi
Sycamore	Platanus occidentalis
Box elder	Acer negundo
Silver maple	Acer saccharinum
Red oak	Quercus borealis, var. maxima
Scarlet oak	Quercus coccinea
White oak	Quercus alba
Chinquapin oak	Quercus muhlenbergii
River birch	Betula nigra
Field corn	Zea mays

On several occasions also the writer has noted whole and partly eaten red oak acorns in well beaten paths leading from the stream partly up the hillside to red oak groves. It is suspected that acorns of other oaks found near the colonies are eaten.

Corn is cut and dragged to the stream beginning with the green stage when it is apparently eaten entire and continuing until after it has matured when the stalks are used in the dam after the ears have been cut off and the kernels eaten. One small dam observed was constructed almost wholly from corn stalks. Farmers whose cornfields the beavers have pilfered have thus far not complained.

No distinct preference has been shown except for corn which is apparently very palatable. Species tallies of cuttings in the vicinity of several colonies gave varying results. The entire list of species is not found near any one colony. In general, the number of cuttings was proportional to the abundance of the plants within 100 feet of the stream bank.

REVIEW

HUBBS, CARL L., and R. W. ESCHMEYER. The improvement of lakes for fishing. Institute for Fisheries Research (Michigan Dept. of Conservation, Lansing, Mich., $1.75 a copy), Bull. 2, 233 pp., 74 figs. (some are compound, some are plates), May 1938.

This book, following that of Hubbs, Greeley, and Tarzwell on the improvement of trout streams, and that of Pirnie on waterfowl management, indicates that wildlife management is coming into its own and that the Michigan Department of Conservation is a leader in the movement. These works are manuals telling what to do and how to do it and the latest of them is replete with practical suggestions. These include discussion of improving shelter (with a chapter on improvement of artificial lakes by Walter W. Aitken and J. Clark Salyer, II), managing plant growths, bettering spawning conditions, regulating the abundance of fish, altering and controlling water level, increasing natural food, decreasing algal nuisances, retarding destructive wave action, preventing erosion and silting, controlling pollution, aerating lakes, modifying temperature, managing fish populations, controlling competitors and predators, treating and preventing diseases, and forestalling overfishing.

Chapters of more general import discuss needs in lake improvement, meeting the requirements of fishes, planning and carrying out betterments, and the practicability of lake improvement and its place in fish management. The bibliography covering 17 pages has been carefully selected and is succinctly annotated. The work has a good index.

This book and others of recent years convince us that wildlife management is distinctly on its way and will not stop unless civilization itself deteriorates.—W.L.M.

NOTES

The cost of reprints from THE JOURNAL OF WILDLIFE MANAGEMENT has recently been given special consideration and a revised schedule of charges is printed on the inside back cover in this issue. It was found that there had been an error in the method of computing the prices previously quoted, which for some unknown reason escaped detection prior to the investigation requested.

To begin at the beginning, the Editor recommended that The Wildlife Society abstain from the more or less prevalent custom of supplying a quota of reprints free to authors. The matter has been approved twice by the Council, once by mail vote and once in assembly. The primary reason was to reduce the amount of business detail to be handled by the officers who serve without pay. The existing arrangement leaves all transactions as to reprints between the author and the printer. Compared to certain other organizations, the Society makes some concessions to writers that are deemed to compensate, at least in part, for the lack of free reprints.

The Wildlife Society assumes all costs of composition, illustration, and

proof correction. Some scientific periodicals charge the cost of part or all of the illustrations to the author. Some restrict the proportion of tabular matter an article may include and send a bill for any excess of this most expensive type of composition. Again cost of author's corrections to proof frequently are assessed. None of these things are done by THE JOURNAL OF WILDLIFE MANAGEMENT.

Even the revised charges for reprints from the JOURNAL average higher than those made by certain periodicals that may be deemed comparable but there are mitigating factors that should be considered. The paper stock used in THE JOURNAL OF WILDLIFE MANAGEMENT is of 25% rag content and special manufacture according to a formula designed to assure lasting qualities and to promote comfort in reading and is, therefore, somewhat expensive. The prices include also an allowance to the printer for handling orders and submitting bills for separates. Further, it should be remembered that in the case of publications which furnish a certain number of reprints free, authors then get the benefit of the always lower prices for additional copies.

The situation is complex, one part following from another; if the one did not exist, the other would be different. The basic reason for our system, as noted in the beginning, is saving the time and energy of editor, secretary, and treasurer, all unremunerated volunteers with plenty to do in their breadwinning positions.

Edward C. M. Richards, an associate of The Wildlife Society, resigned as head of the Forestry Division of the Tennessee Valley Authority, January 31, 1938, after about 4½ years of service. In an article in the *Journal of Forestry* for July 1938 (36(7), pp. 643–652) he criticizes certain policies and the lack of others by the Board of Directors, while upholding the work in wildlife management that has been done. With respect to that subject he charges evasion of research responsibilities and doing of only enough wildlife work to ease the pressure brought in support of it. The apparent reason is holding down expenses so that the power program may be represented as a sound, profit-making business enterprize. The Wildlife Society should be interested in this case involving the welfare of one of its members and of the profession of wildlife management.

EMPLOYMENT SERVICE OF THE WILDLIFE SOCIETY

Space limitations will not permit use of the regular heading and explanation. Three personal notices follow:

KATZ, J. S., Wildlife Research Station, Ohio State University, Columbus, Ohio. Doctor of Veterinary Med. 1936; M.S. Ohio State University, 1938; Wildlife diseases. Research Fellow, Ohio Wildlife Research Station. Training: Ecology and wildlife conservation under Dr. L. E. Hicks. Master thesis; Squirrel parasites Desire fellowship, teaching with research towards Ph.D.

SCHLATTER, E. B., JR., 2259 Regent St., Madison, Wis. A.B. University of Wisconsin, 1/2 year postgraduate work in game management under Aldo Leopold; 2 years experience as Asst. Game Manager on Pine Island Project, Northern Minnesota with Resettlement Administration. Work desired: Wildlife management: administration or field work.

SYPULSKI, JOHN L., P. O. Box 17, Black River Falls, Wis. B.Sc.F., University of Michigan. Majored in wildlife and forestry. 6 yrs. experience in forestry, conservation and wildlife work. U. S. Civil Service ratings—Jr. Biologist 93 (Aug. 1937), Jr. Refuge Manager 86 (Jan. 1938). Desire position in wildlife management.